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Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants

(U.S.) Culp/Wesner/Culp, El Dorado Hills, CA

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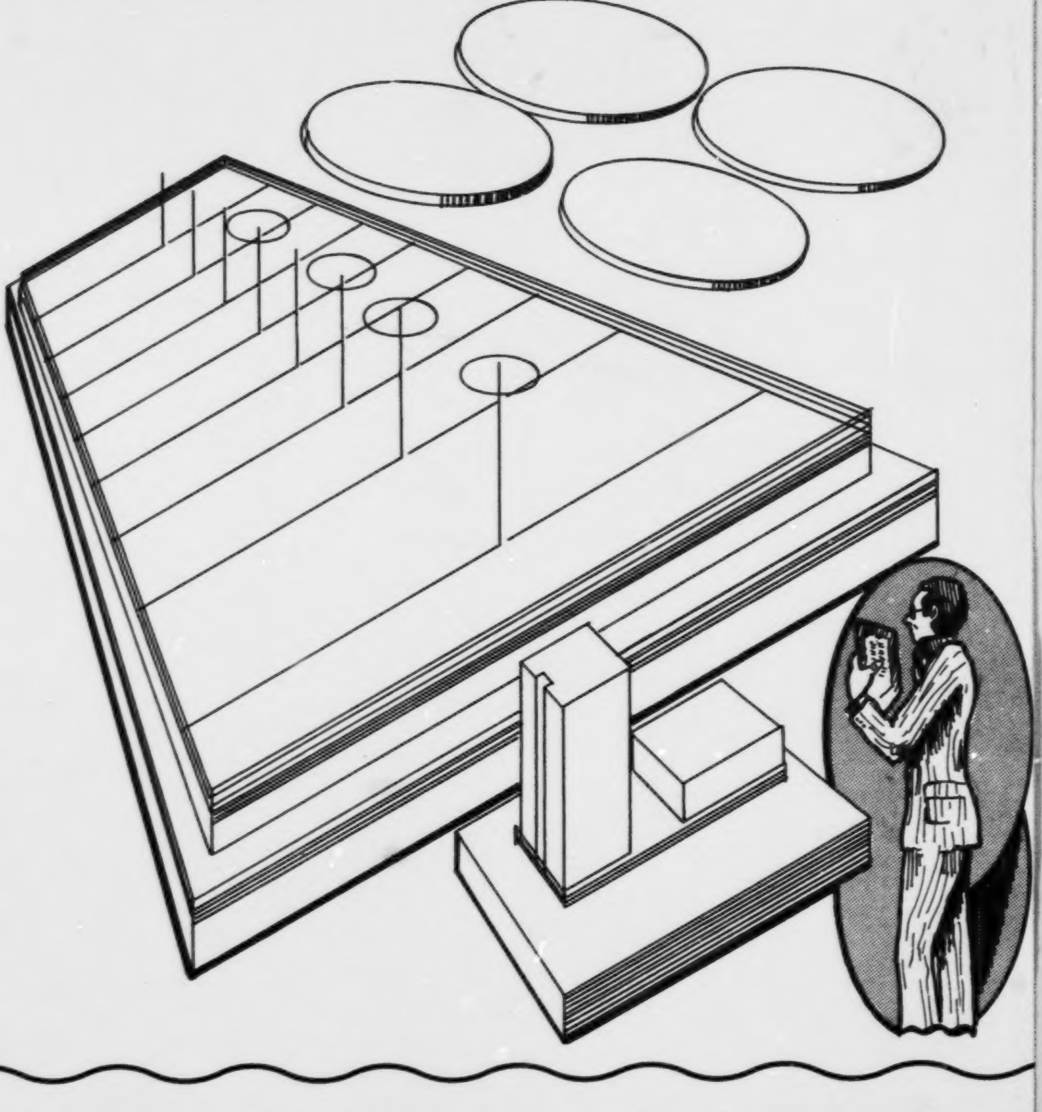

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This inspectors guide is designed to provide state and EPA inspectors with the background necessary to evaluate the operation and maintenance of wastewater treatment plants. This guide also provides the information necessary to make subjective judgements required for plant evaluation. The guide includes checklists for individual unit processes.

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INSPECTOR'S GUIDE:
TO BE USED IN THE EVALUATION
OF MUNICIPAL WASTEWATER TREATMENT PLANTS

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PREFACE

This inspectors guide is designed to provide state and EPA inspectors with the background necessary to evaluate the operation and maintenance of wastewater treatment plants. This guide also provides the information necessary to make subjective judgements required for plant evaluation. The guide includes checklists for individual unit processes.

This guide has been developed simultaneously with a new EPA O&M inspection form. In addition to being a training tool the guide provides a reference source for inspectors. To provide a complete O&M reference file, there are several other EPA manuals that should be used in conjunction with this guide. They are:

1. Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, U.S.E.P.A., Municipal Operations Branch, Office of Water Program Operations, Washington, D.C. 20460, EPA-430/9-78-001.

2. Operations Manual, Sludge Handling and Conditioning, U.S.E.P.A., Municipal Operations Branch, Office of Water Program Operations, Washington, D.C. 20460, EPA-430/9-78-002.

3. Operations Manual, Stabilization Ponds, U.S.E.P.A., Municipal Operations Branch, Office of Water Program Operations, Washington, D.C. 20460, EPA/430-9-77-012.

4. Operations Manual, Anaerobic Sludge Digestion, U.S.E.P.A., Municipal Operations Branch, Office of Water Program Operations, Washington, D.C. 20460, EPA-430/9-76-001.

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I. OVERALL PLANT MANAGEMENT

Proper operation and maintenance of a wastewater treatment plant requires qualified staff and a certain degree of effort on the part of the operating agency. This effort can be expressed in terms of budgets, industrial waste ordinances, and willingness to hire and maintain qualified personnel. The overall plant management review should include budgets, user charges, industrial waste ordinances and enforcement, staff numbers and qualification (certification), salary levels, promotion opportunity, maintenance management, and more. To simplify, the overall plant management can be divided into the following areas:

- Staffing and training
- Revenue program
- Budgeting
- Maintenance management
- Records keeping
- Sampling and laboratory testing

Staffing and Training

A major part of evaluating the staffing and training at a wastewater treatment plant requires some subjective judgement by the inspector. Subjective judgements are difficult to make without several years of experience. These evaluations are often complicated by special circumstances found within local or regional areas. However, after reviewing several plants subjective judgements should be easy to make. The first step is to review the staff numbers and certification level. Staffing levels for different types of plants and unit processes are published in two EPA publications, "Estimating Staffing for Municipal Wastewater Treatment Facilities", 68-01-0328, March, 1973(1), and "Estimating Costs and Manpower Requirements for Conventional Waste Treatment Facilities", 17090 DAN 10/71, October, 1971(2). These are for guidance only. Local conditions, number of shifts, and days per week of operator coverage will determine the right staffing level for each plant. If the staffing numbers are close to that recommended by the publications, then the numbers should be adequate. Certification requirements are different for each state. Some are mandatory and some are voluntary. The operations staff certification levels should be compared to the applicable state recommendations.

The staff training opportunities should be reviewed for availability of courses and operating authority policies for providing expenses and time off from work. The training program should be available to all personnel rather than supervisory staff only. The agency budgets funds for training but there is no guidance as to the proper amount, due to area constraints and cost variations. There should be some planned training effort by the agency for training new operators and keeping trained operators up to date with new processes and operations techniques.

The most difficult analysis to make is that regarding operator competency. Unfortunately, many courses and certification exams neglect areas of process control. Many operators are well trained in the mechanics of treatment plant operation but have no knowledge as to proper control techniques to optimize unit process performance. The only way to judge operator competency is to compare treatment results with other agencies having similar systems and waste characteristics.

Other areas to review include the O&M staff salary schedule and promotion potential. A national salary survey of treatment plants and collection systems was published by the Water Pollution Control Federation in their May 1977 issue of "Deeds and Data". This survey result provides some guidance as to average salaries being paid to O&M personnel. Promotion potential is important for minimizing staff turnover, which in turn minimizes training requirements.

Revenue Program

A well designed revenue program will not insure good operation and maintenance but will provide the funds necessary to operate and maintain the facility as well as money for future replacement of equipment. All facilities that receive federal grant funds after 1974 should have approved revenue programs.

There can be many variations in revenue programs. Generally, the revenues should equal costs (including buildup and maintenance of a reserve fund). The revenues should be obtained by a system of equitable user charges. Equitable user charges are determined depending on local constraints. For example, if the system receives only domestic waste, the users would pay based on a flat rate per hookup for each family. If there is an industrial user, then the user charge should be based on the contribution in terms of flow and strength of wastewaters. If the wastewater strength is basically equivalent to domestic waste, then the user charge should be based on flow only. Three example models are shown in Appendix B to federal regulations, "Construction Grants for Waste Treatment Works", found in the Federal Register dated February 11, 1974.

Usually, if the operating authority has a revenue program in effect, it will be acceptable. This information is normally not available at the plant and must be obtained at the authority's main office.

Budgeting

One of the most neglected areas with small treatment plants is the budget. Often workers are divided between operating a wastewater treatment plant and other duties (e.g. water plant, sewer lines, street repair, etc.) Chemicals may be purchased for use at several places. The net result is that no one really knows the cost of operating the wastewater treatment plant. References 1, 2, and 3 can provide information as to the cost for operating and maintaining most unit processes. There are many publications available on costs but those showing total plant cost should be avoided. Instead, the cost for individual unit processes should be determined and the total plant O&M cost determined by adding the individual unit costs.

The correct budgeting procedures should include allowances for emergency repairs, special expenses such as operator training and schools, and the planned expenses for salaries, utilities, and bond repayment. As with revenue programs there are no one or two "correct" methods for budgeting. A budget should be prepared so that the actual costs of operation and maintenance can be reviewed in several categories such as salaries, electricity, chemicals, fuel, laboratory cost, and training.

Maintenance Management

The publication, Maintenance Management Systems for Municipal Wastewater Facilities provides an excellent guide for determining adequacy of maintenance systems. A simplified version of their evaluation guidelines follows:

1. Is there an equipment numbering or other identification system to aid in locating and identifying all major items of equipment?
2. Is there a system for maintaining nameplate data and other essential information on all major equipment items within the treatment system?
3. Does the maintenance record system provide for listing preventive maintenance (PM) tasks, giving their frequency and recording the PM work performed?
4. Does the maintenance record system provide for recording corrective maintenance work performed?
5. Does the maintenance record system provide for recording such information as maintenance manhours, spare parts or components used in repair and name of individual performing each job?
6. Does the maintenance record system provide for recording all maintenance related costs and can these costs be readily compiled for use in maintenance budget preparation?
7. Are miscellaneous maintenance related documents such as as-built drawings, construction specifications and photos, shop drawings and manufacturers' literature properly filed and indexed and readily available to maintenance staff?
8. Is some form of schedule chart or priority list provided to assist maintenance supervisors in controlling maintenance tasks?
9. Are there planned and scheduled preventive maintenance (PM) tasks for all major equipment items within the treatment system?

   a. Are PM frequencies based upon manufacturers' recommendations and by inspection?

   b. Does the existing maintenance organization permit the proper scheduling of required PM and take into account the corrective maintenance manhour requirements?

10. Are potential corrective maintenance tasks adequately considered in maintenance planning?

11. Is there a work order system that satisfies the treatment system's maintenance requirements?

12. Are manpower management techniques used effectively to obtain maximum utilization?

13. Is there some form of labor standards to assist in preparing accurate work estimates for repetitive maintenance jobs?

14. Are contracting services utilized for maintenance tasks beyond staff capability.

15. Is there a storeroom or storage area to assist in controlling the flow of spare parts, components and maintenance supplies?

16. Have manufacturers' recommendations been reviewed and each major equipment item's maintenance requirements been studied to determine what maintenance items should be maintained?

   a. Has a system been developed to monitor qualities of all maintenance items kept in stock?

   b. Have minimum and maximum quantities been established for all maintenance items kept in stock?

   c. Is there a purchase order system that adequately controls the procuring of maintenance items?

17. Is there a catalog or index system to assist in identifying and locating a given item in the storeroom?

18. Is there a storeroom ticket or withdrawal slip to use when maintenance items are taken from stock?

19. Is there a maintenance organization chart that satisfies treatment system requirements?

20. Is the maintenance organization chart reviewed and updated as required?

21. Are there job descriptions for each job title within your maintenance organization?

22. Are job descriptions kept up to date and made available to maintenance personnel as required?

23. Prior to initiating any program to correct deficiencies in a maintenance job, is a thorough analysis of this job performed?

24. Is there a maintenance training program that satisfies the maintenance objectives of the treatment system?

25. Are maintenance costs broken down by maintenance categories such as preventive maintenance, corrective maintenance and major repairs or alterations?

26. Is there a system of cost codes or charge numbers for allocating labor and materials to specific maintenance jobs?

27. Is there a system for recording the maintenance cost history of all major equipment items?

28. Is there a system for compiling cost information for use in budget preparation and maintenance cost studies.

29. Is there a system for recording contract maintenance costs so they can be used in preparing maintenance budgets?

The above evaluation would apply mainly to large, complex systems. Although all the details would not be necessary for a small system, the principles would be applicable. Basically, any system should provide information as to costs and materials necessary for maintenance of all items in the plant.

Records Keeping

The three major areas of record keeping are maintenance, laboratory (unit process and plant performance), and cost accounts. Maintenance records were discussed in the previous section. Laboratory records can be divided into two areas. One area is that required for NPDES permits reporting. Preprinted forms are usually provided by the enforcement agency. The other area is individual unit process control test results. Historical record keeping of individual unit processes is extremely important for process problem solving or troubleshooting. Often process upsets occur during certain seasons of the year or during certain unusual events such as weather extremes or specially planned social activities where large numbers of people visit from outside the service area (e.g. small tourist towns). Records of process performance will show when the previous problems occurred and when corrections were made. The corrections made should be noted in the record or in an operators diary. This way previously attempted corrective action can be reviewed to see how effective it was. This procedure can be accomplished very simply through the use of trend charts. When a trend is reversed the probable reason should be written down.

Regardless of the procedure used there should be a means of identifying and recording periods when process upsets occurred.

Cost accounts are the most often neglected area in small wastewater treatment plants. When good records are kept, the operating agency is more likely to be aware of the need for replacing high maintenance equipment. For example, a pump requiring frequent costly repair should be replaced. This decision is a judgement decision which can only be made if accurate records have been kept. General utilities can be a major cost factor in a treatment plant. If fuel costs increase at a faster rate than the unit cost then there is a chance that fuel is being wasted or a unit being operated improperly (e.g. incinerator temperature too high). There is no one correct system, but the system used should provide the information necessary to determine a detailed breakdown of all expenditures required to operate and maintain the wastewater treatment system.

Often, these records will be kept at the agency's main office or the city hall. The inspector should either request in advance that the records be available at the treatment plant or be prepared to visit the agency's main office.

Sampling and Laboratory Testing

Proper procedures and techniques for laboratory analyses are presented in references 4, 5, and 6. A facilities inspector should be sure that laboratory personnel are aware of the proper techniques. He should also observe a sampling procedure and one analysis to see if the staff personnel are conscientious in doing their work.

II. SAFETY

General

Management has the primary responsibility for safety. The inspector should examine the plant safety program and verify that a complete and effective program has been established. He should also observe plant personnel to verify that they actually perform their duties in a safe manner.

Certain process units involve particular hazards, and these will be discussed in greater detail later in this section. The requirements of an effective overall plant safety program are discussed here. Reference 8 provided much of the background for development of this section.

Management's responsibility for safety consists of four major areas:

1. Providing a safe place to work.
2. Providing safe equipment and tools.
3. Hiring only qualified personnel or personnel with the aptitude to be trained.
4. Training workers for job skills as well as safety precautions.

The first two areas are self-explanatory. The plant has to be designed and constructed so that unsafe conditions can be avoided. Then the facility must be maintained to prevent unsafe conditions from developing. Some of the features of plant design and maintenance relating to safety which the inspector should check include:

Handrails should be provided around all basins and openings.

All stairs, walkways, and platforms should be free of grease, oil, and debris, and should be well lighted.

Adequate ventilation systems should be provided for all enclosed spaces.

Life preservers and throwlines should be provided adjacent to all basins, ponds, and lagoons.

Protective guards should be provided on all rotating machinery.

Protective guards and handrails which can be removed for maintenance should be in place.

Where flammable gases may be present, explosion-proof electrical equipment should be provided and all bolts, gaskets, globes and guards should be intact.

Carbon dioxide fire extinguishers should be provided adjacent to motor control centers and automatic control systems.

Signs should be provided at the entrances of all wetwells and rooms in which toxic or flammable gases may be present.

Signs should be provided at the entrance to all rooms in which high voltage electrical equipment is located.

Instrumentation for the detection of toxic and flammable gases and low oxygen levels should be provided and should be operational.

All boats at lagoons should be provided with at least two life jackets.

All vehicles should be equipped with appropriate safety equipment, including lights, horns, windshield washers and fire extinguishers.

Pressure vessels should be operating within their design rating and should have a pressure relief, where appropriate.

A list of minimum recommended safety equipment is shown on Table 1(8).

TABLE 1. MINIMUM RECOMMENDED SAFETY EQUIPMENT FOR WASTEWATER WORKS PERSONNEL

Equipment	Use
Portable air blower (gas motor or electric motor operated)	Ventilating manholes and other enclosed subterraneous structures
Electric explosion-proof lantern	Illumination in tanks or sewers where gas may be present
Safety harness	For workers entering deep manholes or tanks
Hose mask with hand blower and 50-ft hose	Respiratory protection in all gas and vapor atmospheres including oxygen deficiency
Self contained breathing apparatus for plants using chlorine	Respiratory protection against chlorine gas leaks
Explosion and oxygen meters	Monitor air around pure oxygen processes

The third area is difficult when hiring new employees. New employees may not be qualified for their new job but may be trained. Those that do not have the physical or mental capability to do the work or do not possess the necessary aptitude to perform certain tasks will be more susceptible to accidents. It is therefore, important to see that new employees were properly evaluated before hiring them and time was spent with them to see that they are given proper instructions on both job skills and safety training.

The fourth area is an extension of the third in that a program should be provided for all employees to continually be given skill and safety training so that chances for accidents are minimized.

Each safety program should include a list of safety rules for all employees to learn and use. An inspector cannot enforce safety rules but a written set of safety rules should be available to all employees.

The safety rules should include the following areas(9):

1. Personal hygiene
2. Fire protection
3. Protection around openings
4. Tools & safety equipment
5. Accidents & first aid
6. Safety drill procedures
7. Gases
8. Created hazards
9. Accident preventation
10. Driving safety
11. In-plant traffic
12. Machinery guards
13. Ventilation
14. Gas utilization
15. Structures
16. Housekeeping
17. Safe operation
18. Electrical equipment
19. Procedures for one-man shifts
20. Laboratory

A detailed, well-written safety manual should include the above plus specific rules for individual unit processes.

Chlorination

Chlorine is a highly toxic gas which may be fatal if inhaled in sufficient quantity. The presence of chlorine is easily detected however. A concentration of 3.5 parts per million of chlorine by volume is detectable. At concentrations between 15 and 30 parts per million significant irritation of the mucus membranes and nasal linings will occur. Exposure to chlorine at a concentration of 1,000 parts per million will result in fatalities in a very short exposure time. Most chlorination facilities using gaseous or liquid chlorine are designed to rigorous safety standards presenting minimum hazards to operating personnel. An adequately designed facility will have continuously monitoring chlorine leak detectors which sound an alarm in the event of a leak. The following safety requirements should be met for any chlorine application facility.

1. Chlorination equipment should always be placed in an adequately ventilated room and isolated from other working areas. Ventilation should be provided with fan at floor level since chlorine is heavier than air. Access should be from an outside door.

2. Provisions should be made to continuously ventilate the area surrounding the chlorine cylinders and the chlorination equipment.

3. Equipment should be provided for continuous monitoring of the air in chlorine storage and application area.

4. Proper instructions and supervision to workers charged with responsibility of chlorination equipment should be provided.

5. Proper and approved self-contained breathing apparatus for persons working where there is a possibility of exposure to chlorine gas fumes should be provided, should be stored outside the area of danger, and should be quickly accessible.

6. Combustible or inflammable materials should never be stored near chlorine containers or application equipment.

7. Heat should never be applied to any chlorine container.

8. A water supply to keep chlorine containers cool in case of fire should be provided.

9. Several appropriate emergency container leak repair kits should be stored near the chlorine application facility.

10. Plant safety rules should require that any leak in storage cylinders or application equipment be attended by at least two persons wearing self-contained breathing apparatus.

11. Emergency shower and eye wash facilities should be provided adjacent to entry doors into chlorine storage or application facility.

12. First aid procedures should be developed and all personnel handling chlorine should be familiar with their application. These procedures should be posted in the chlorine area.

14. Fire protection should be provided by class C fire extinguishers (for energized electrical equipment) and located in the area immediately adjacent to the chlorination room.

15. Procedures should be developed to handle chlorine leaks from storage cylinders or application equipment. Periodically operating personnel should review these procedures in a hypothetical emergency situation.

Ozonation

Ozone is a highly toxic gas which may be fatal if inhaled in sufficient quantity. The maximum acceptable limit for personnel exposed to ozone is 0.1 ppm by volume. Exposure to 100 ppm by volume for a period of 1 minute will cause significant nasal and mucous membrane irritation. However, since ozone has a very noticeable odor at concentrations far below harmful or toxic levels, it is immediately detected. Concentrations up to 20 or 30 times higher than this and prolonged exposure over many hours are required before the gas can be harmful. See Figure 1. The hazards to operating personnel by ozone exposure is minimized because any escape of ozone from a treatment system can be quickly stopped by turning off the electric supply. Furthermore, equipment used to generate ozone is protected by fail safe devices which utilize continuous ozone sensors.

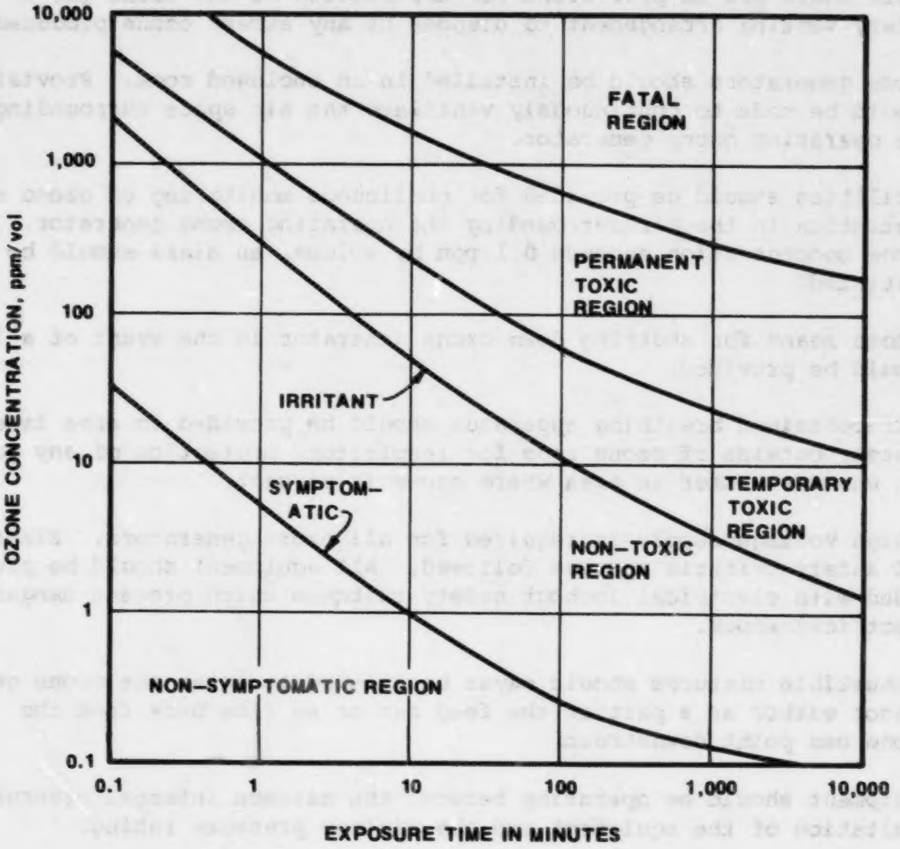

Figure 1. Ozone toxicity.

The following safety requirements should be met for any ozone application system.

1. An ozone generator should never be operated in a closed environment where there are no provisions for destruction of the ozone gas or a safety venting arrangement to dispose of any excess ozone produced.

2. Ozone generators should be installed in an enclosed room. Provisions should be made to continuously ventilate the air space surrounding the operating ozone generator.

3. Facilities should be provided for continuous monitoring of ozone concentration in the air surrounding the operating ozone generator. If ozone concentration exceeds 0.1 ppm by volume, an alarm should be initiated.

4. Remote means for shutting down ozone generator in the event of a leak should be provided.

5. Self-contained breathing apparatus should be provided in area immediately outside of ozone room for respiratory protection of any person who must enter an area where ozone is present.

6. A high voltage supply is required for all ozone generators. Electrical safety criteria must be followed. All equipment should be provided with electrical lockout safety switches which prevent danger of electrical shock.

7. Combustible mixtures should never be allowed to enter the ozone generator either as a part of the feed gas or as flow back from the ozone use point downstream.

8. Equipment should be operating between the maximum internal pressure limitation of the equipment and the minimum pressure rating.

9. Provisions should be made to insure that the ozone distribution system will not allow liquid or moisture to back flow into the generator.

10. Safety signs should be placed outside each door leading to the ozone generator room. The signs should (a) restrict entry to authorized personnel only (b) prohibit smoking or open flames in the generator room (c) warn of the existence of ozone equipment and the possible presence of ozone gas and (d) advise personnel to leave the room immediately if the odor of ozone is detected.

11. When performing service work on ozone generators, plant rules should require that at least 2 persons be present.

12. Plant rules should require that only experienced maintenance technicians familiar with the construction and operation of the apparatus should be allowed to open cabinet doors, remove side panels and otherwise service the equipment.

13. Fire protection should be provided by Class C fire extinguishers (for energized electrical equipment) and located in the area immediately adjacent to the ozone generator room.

14. If pure oxygen is generated on-site and used to supply the ozone generation equipment all appropriate safety standards associated with the handling and use of pure oxygen must be observed.

Activated Carbon Columns

Activated Carbon can adsorb oxygen from the environment. Forced air ventilation or respiratory protective equipment should be provided for entry into carbon columns, wash tanks, and carbon regeneration furnaces. Other safety precautions pertaining to furnaces should also be observed.

Recarbonation

Under certain conditions, carbon dioxide can be dangerous, and special safety precautions should be observed. Prolonged exposure to concentrations of 5 percent or more CO_2 in air may cause unconsciousness and death. Self-contained breathing apparatus or hose masks should be stored near basins and worn when working in the area.

Recarbonation basins must be located out-of-doors, and enclosed structures must not be constructed above the basins because of the danger of excessive amounts of CO_2 accumulating within the structures.

There are many other detailed safety considerations associated with liquid CO_2 handling and use. These should be obtained from the supplier.

Ferric Chloride Feeding

Dust from ferric chloride can be damaging to the respiratory system if inhaled. In plant areas where the dust may be present, such as bag handling areas, unloading areas, or around open feeders, lightweight filter masks and tight fitting safety glasses with side shields should be available and worn by workers.

Great care should be taken to AVOID THE CONTACT OF ANHYDROUS FERRIC CHLORIDE WITH ANY PART OF THE BODY, and especially with the eyes. The moisture present in the eyes or on the skin can cause sufficient heat to burn the skin. Ferric chloride solutions should be handled with the same care as acid solutions, since they can cause burns similar to those caused by acids. They are also injurious to clothing and cause difficult-to-remove stains. Personnel handling anhydrous ferric chloride or ferric chloride solutions should wear overalls, rubber apron, rubber gloves and chemical goggles. Floors, walls and equipment which are subject to splashing should be protected with corrosion-resistant paint or rubber mats.

Plant operators should be instructed in proper procedures for handling ferric chloride and these procedures should be posted wherever it is stored, handled, or fed. These instructions should include:

> If anhydrous ferric chloride comes in contact with the skin or clothing, DO NOT WASH IMMEDIATELY WITH WATER. Severe burns can result from the high heat produced when anhydrous ferric chloride is dissolved. Wipe off the excess ferric chloride first with a cloth, and then flood rapidly with large amounts of water.
>
> If liquid ferric chloride comes in contact with the skin or clothing, wash it off immediately and throughly with water.

The following additional safety features should be checked to ensure proper operational conditions:

1. The chemical storage tanks should be specifically designed to handle the particular chemical. These considerations include air-tight for hygroscopic chemicals and rubber lined or similar for ferric chloride.
2. Storage bins should be large enough to avoid continuous filling which requires the presence of an operator all the time.
3. The chemical storage and feed rooms should be well ventilated and should include special dust collectors when handling fine powdered chemicals.

Lime Feeding

Dust from lime can be irritating to the respiratory system if inhaled. In plant areas where the dust may be present, such as bag handling areas, unloading areas, or around open feeders, lightweight filter masks and tight fitting safety glasses with side shields should be available and worn by workers.

The problem of protection from quicklime burns is serious, particularly in hot weather when workers are perspiring freely. Besides using eye protection and respirators workers exposed to quicklime dust should also wear proper clothing, including long-sleeved shirt with sleeves and collar buttoned, trousers with legs down over tops of shoes or boots, head protection, and gloves. Clothing should not bind too tightly around neck, wrists, or ankles. Protective cream should also be available for application to exposed parts of the body, particularly neck, face, and wrists.

Freshly slaked lime in stiff putty or milk form can produce burns when hot. After slurry is cool, contact with skin is virtually harmless, the principal effect being removal of natural skin oils. Therefore, workers who frequently handle lime slurry should oil their skin, where exposed, daily. Something similar to a petroleum jelly should be available for this use to help prevent chapping and thus reduce danger from burns or infection.

Workers inspecting or cleaning slakers should have safety goggles available and should wear them.

Showers should be provided to permit workers to shower after handling lime.

Instructions should be posted wherever lime is handled for the treatment of lime handling accidents.

An efficient dust collecting and removal system should be provided wherever lime is handled. An industrial vacuum should be provided for cleaning up lime dust around and on equipment.

Quicklime bags should be stored in a clean, dry place to avoid moisture pickup. Otherwise the intense heat generated from accidental contact with water may be enough to start a fire in nearby flammable materials.

An important slaker safety measure is the installation of a thermostatic valve to prevent overheating and possible explosion. This could occur if the water supply fails and the lime feed continues, allowing the lime to overheat and produce excessive steam. The safety valve delivers a supply of cold water as soon as maximum safe slaker temperature is exceeded. An added safety feature is a high temperature alarm device.

Other Chemical Feeding

Dust from any dry chemical can be irritating to the eyes and respiratory system. In plant areas where the chemical dusts may be present lightweight filter masks and tight fitting safety glasses with side shields should be available and worn by workers.

Dry polymer powder can be extremely irritating to eyes. Eye protection should be available and worn when handling powder. Instructions should be posted to flush with water if powder gets in the eyes. The major hazard with polymer handling is powder spilled on the floor which becomes wet, causing extremely slippery surfaces. This powder remains slippery until washed down with large volumes of water.

The following safety features should be checked to ensure proper operational conditions:

1. The chemical storage tanks should be specifically designed to handle the particular chemical. These considerations include air-tight for hygroscopic chemicals.
2. Storage bins should be provided with dust collectors and vents.
3. Storage bins should be large enough to avoid continuous filling which requires the presence of an operator all the time.

4. The chemical storage and feed rooms should be well ventilated and should include special dust collectors when handling fine powdered chemicals.

5. Operators should be instructed to avoid using the same conveyor mechanism for more than one chemical. This is especially important with quicklime and chemicals containing moisture as fire and explosions could occur.

Furnaces and Incinerators

Safety measures for furnaces and incinerators should be observed at all sludge heat treatment and wet air oxidation steam generators, multiple hearth incinerators, fluidized bed incinerators, lime recalcining furnaces, and carbon regeneration furnaces. The protective measures listed should be provided wherever appropriate and the procedural measures should be posted in a prominent place:

1. No smoking should be allowed around natural gas lines or when checking the system for leaks. No smoking signs should be posted.

2. Protective clothing and face shield should be worn when repairing or lighting furnaces and incinerators.

3. A colored plate should be provided for use when looking into an operating hearth to protect the eyes from the bright flame.

4. A sign should be posted introducing operators to open hearth access doors with caution, to not stand in front of them when they are initially opened, and to close them as soon as possible.

5. Flame safety devices should be fully operational.

The appropriate procedures for hauling of lime and activated carbon should be observed for recalcining and regeneration furnaces.

Heat Treatment

The proper safety procedures for furnaces and incinerators should be observed for heat treatment steam generators.

The following safety features of the heat treatment process should be checked:

1. Operators should be instructed that if at any time during operation the system temperatures are abnormally high, the air compressor should be stopped and the system switched from sludge to water. Abnormally high temperatures are shown in the manufacturer's manuals and should be posted.

2. Any inspection or cleaning should be done with that section of the system completely depressurized. Liquids under pressure can cause serious harm to personnel if suddenly discharged.

3. Proper protective equipment should be available and worn during inspection and cleaning per manufacturer's recommendations.

4. Observe proper handling procedures when using acid solutions for cleaning. Recommended safety procedures should be obtained from the supplier, implemented, and posted prior to handling of any acid in the plant.

5. Operators should be instructed that vessels should be well ventilated and completely isolated before entering. A vessel should never be entered without a lift line held by someone outside the vessel and a reliable source of air inside the tank.

6. Carbon coatings on high pressure air compressor discharge valves indicate too much oil is being used to lubricate the cylinder. Failure to correct this could result in fires at the discharge of these cylinders.

7. Proper masks should be available when working around the supernatant and liquor because of the gases and odors.

Anaerobic Digesters

The following safety features should be checked in anaerobic digesters, around digester gas-fired boilers and engines, wherever anaerobic sludge is discharged, such as at drying bed and lagoons, and any other locations where digester gas or anaerobic sludge may be present.

1. Since digester gas is explosive when in contact with air, there should be no smoking, open fires or flame wherever gas may be present. No smoking signs should be posted.

2. Operators should be instructed to observe the following when entering a digester:

   (a) Provide adequate ventilation - be sure exhaust fan is on.
   (b) Always have two persons present.
   (c) Use safety harness equipment with safety line.
   (d) Check for gases with explosimeter.
   (e) Be careful of footing.
   (f) Use bucket and rope to lower tools and equipment.

3. Positive pressures should be maintained in all gas collection systems.

4. Digesters accidentally drained below the operating range of the floating cover introduce air into the digester causing an explosion hazard. In this case all personnel should be familiar with procedures for constant purging with a noncombustible gas.

5. Periodic checks should be made of the gas collection/storage system for leaks.

6. Regular checks should be made on the operation of the following equipment:

   (a) pressure regulators
   (b) pressure relief valves
   (c) flame arresters
   (d) waste gas burners
   (e) gas engines
   (f) boilers
   (g) automatic gas and pilot valves
   (h) gas condensate traps
   (i) explosive atmosphere detectors

7. If it is necessary to enter a sludge pumping station:

   (a) A blower should be provided and used for ventilation because toxic gases can accumulate in low places. A sign warning of possible toxic gases should be present.

   (b) Safety harnesses should be available and be worn.

   (c) At least two persons should remain at the surface in case of an injury or accident.

Pressure Filtration

1. For safety, filter press installations are usually equipped with a photo-electric light that surrounds the press and stops the closing mechanism if the light beam is interrupted. This system must be checked for proper operation:

   (a) Check that the light curtain is illuminated after switching it on.
   (b) Check that the closing motor stops when the light beam is blocked.

2. Face shields and rubber gloves should be worn during acid cleaning of media.

3. The feed pumps develop high pressures and the press should not be opened until these pressures are relieved.

II. PLANT HYDRAULICS

Plant hydraulics includes liquid flow through the plant as well as sludge flow to processing units and/or disposal areas. The objectives of analyzing the hydraulics of a system are to insure that raw sewage is not backed up into the collection system or bypassed around the plant and that there are no flow restrictions that could inhibit unit process performance.

The first area to inspect is the raw sewage pumping station and nearby (upstream) manhole covers. Visual inspection should be adequate to determine if the wet well flooded or if sewage spilled out through the manhole. Usually, an overflow will leave a stain or deposit and is obvious. The individual and total station pumping capacities should be noted. Standby pumps should be adequately sized to maintain pumping station capacity with the largest pump out of service.

Inadequate hydraulic capacity in the unit processes will often be obvious from old high water lines or open tanks or flooded weirs on clarifier launderers. If only a portion of the weirs on one tank are flooded, then the weirs are improperly leveled and should be adjusted. If there are multiple units and only one unit has flooded weirs, then the problem is unequal flow distribution. Unequal flow distribution is a common problem when taking flow from multiple units through a common distribution channel leading to other multiple units. This problem is compounded during extremely high or low flow periods. Inspection of a facility in the morning hours will generally reveal if there are distribution problems with the morning's peak flow.

Recycle flow pumping and piping are critical to most secondary treatment processes. The problems most commonly found are insufficient capacity and uneven sludge withdrawal from clarifiers. Insufficient capacity is difficult to determine without a detailed analysis, but will usually result in less than expected treatment efficiency. (Proper metering would make this a simple analysis but meters are not always installed or properly calibrated). Uneven withdrawal from clarifiers results from pumping sludge from two or more clarifiers simultaneously through a common header pipe. This is more critical with unequal pipe lengths from the clarifiers to the pump. If two identical clarifiers receiving the same amount of influent have different appearances (e.g. one - clear, one - cloudy), then unequal drawoff of sludge is possible.

Inadequate sludge pumping capacity or pipeline size can result in sludge being stored in unit processes which were not intended for storage. This results in poor performance of sludge treatment processes. Unit process performance records should be reviewed and if less than optimum performance is achieved the one possible cause could be lack of hydraulic capacity in the system pumping sludge to the next unit process.

Hydraulic capacity of sludge pumping systems will appear to be lacking if dewatering units are not performing properly. A system may have been designed for a dewatering sludge to 15% solids. If the dewatering process performance provides a sludge with 10% solids then the sludge pumping system may not be sufficient to pump the additional water. The dewatering system design performance should be compared with the actual performance before making conclusions on the hydraulics of the sludge transfer system.

IV. COMPATIBILITY OF UNIT PROCESSES

In the following sections and in referenced design or operation manuals anticipated unit process performance is discussed. The individual plant being reviewed was designed with certain process performance standards in mind. Occasionally a system will be reviewed where a unit process is not performing as expected. The unit may be properly designed and operated but the performance is still not acceptable. One possible cause is that the unit is not compatible with the waste stream being treated. An example of this situation is gravity thickening of waste activated sludge. A gravity thickener will usually not effectively thicken waste activated sludge. Another example is conventional filtration of lagoon effluent without chemical pretreatment. Primary sedimentation of waste activated sludge, although a common practice, can hinder primary treatment performance. Microscreening of chemical sedimentation effluent is generally not effective. Pumps designed for general water pumping are not effective with sludge pumping (e.g. closed impeller pump). Certain chemical sludges can only be pumped by systems constructed with special materials.

Related to unit process compatibility is individual unit process compatibility with the waste being treated. Process designs should be carefully reviewed to see that the application was properly determined. For example, a filtration process was designed to obtain a suspended solids effluent of less than 5 mg/l. This was also based on a secondary (activated sludge) effluent of less than 30 mg/l. If the secondary treatment system is changed to aerated ponds then the filtration system will not operate as designed.

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V. UNIT PROCESS EVALUATION SECTIONS

The following chapters consist of a brief discussion of each unit process followed by a suggested checklist. These checklists are provided to aid the inspector and should not be considered as required for each inspection. They are intended mainly for new inspectors or experienced inspectors who are reviewing a process which they have not previously inspected.

1. RAW SEWAGE PUMPING STATIONS

Process Description

Raw sewage pumping stations are used to lift or pump the raw sewage into a treatment facility when the influent sewers or interceptors are at too low an elevation to allow the sewage to flow by gravity into the treatment facility.

The pumps most commonly used for pumping raw sewage include centrifugal pumps, screw lift pumps and air lift ejectors. Each of these systems is described in detail in Reference 1.

Typical Design Considerations

The basic criteria by which pumping stations are rated are their capacity (gpm or mgd) and pumping head (feet) capability. Because of the many kinds of pump designs and capacities, the manufacturers performance curves should be used to provide the required information on discharge, power requirements, and head characteristics for a specific pump. Every pumping system should have been analyzed in detail and a "system-head" curve developed which describes the operation of the system. An example of such a curve is shown in Figure 1-1, and shows the static head, frictional head and total dynamic head for the system. The point of crossover of the pump curves and the pipe system curve represents the operational point. This point delineates the capacity of the pumping system and the total dynamic head. Also shown in Figure 1-1 are curves for the horsepower required and the net positive suction head (NPSH) for varying flow rates. Depending on the type of pump, the number of pumps operating, and the discharge pipe diameter and length, the shape of the curves could be altered considerably.

Typical Performance Evaluation

A pumping system is normally evaluated by checking the operating point in the "system-head" curve, similar to the one shown in Figure 1-1. The evaluation requires the following procedure:

1. Determine the physical conditions that affect the pumping operation:

Height of sewage above pump impeller in wet well (suction head)	= 6 ft
Height of sewage at pump discharge point above impeller (discharge head)	= 30 ft
Frictional losses in suction and discharge piping (based on diameter, length, bends & valves in lines)	= 5 ft
Pump efficiency	= 85%
Motor efficiency	= 90%
Voltage to motor	= 460 volts
Plant flow (mgd) from influent flume	= 5 mgd
gallons/minute = mgd x 1,000,000/(24x60)	= 3472 gpm

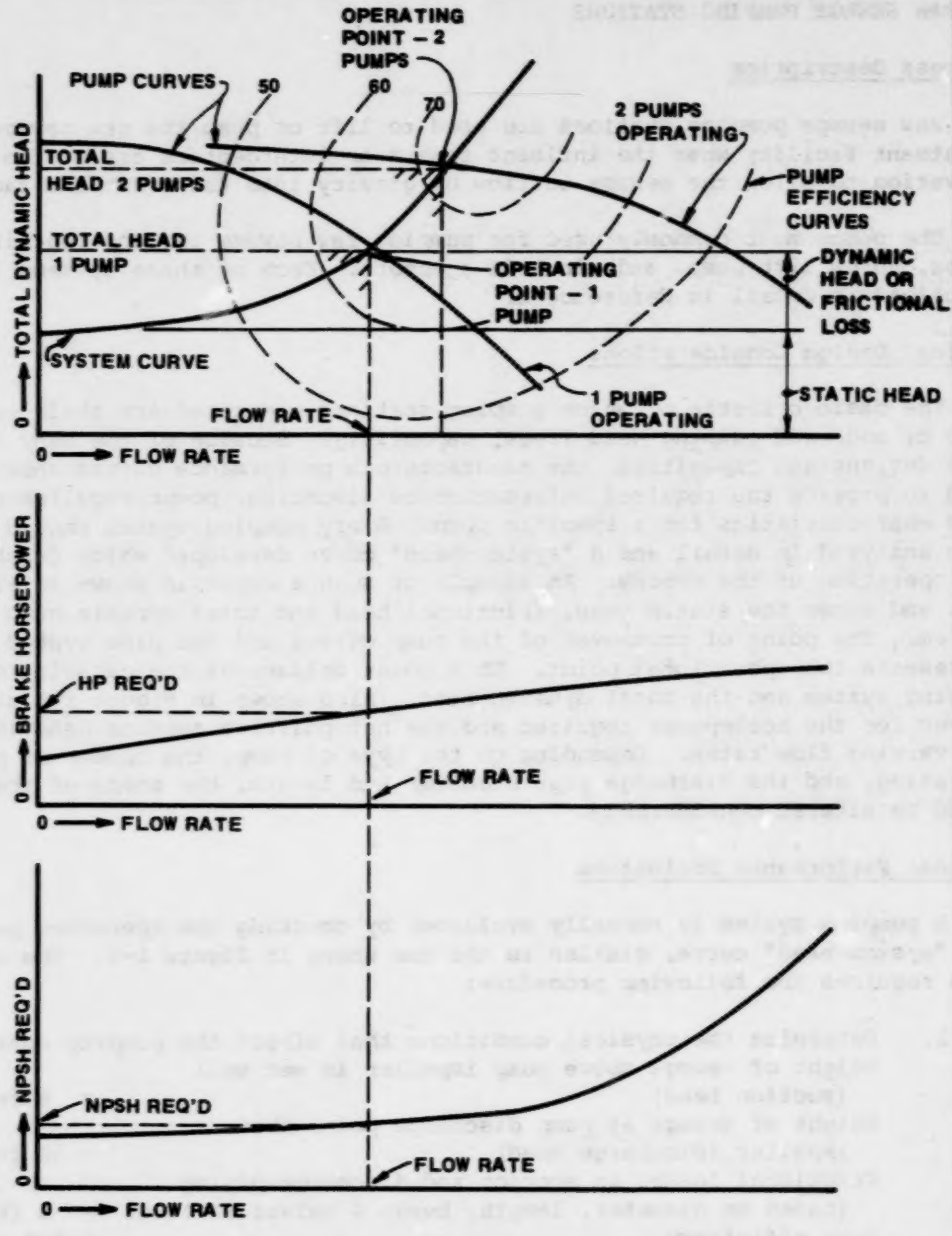

Figure 1-1. System-head pump curves.

2. **Determine the head characteristics against which the pump is operating:**

Static head (ft) = Difference in elevation between discharge and suction (or difference in elevation between water surface in wet well and water surface at discharge point)

= 30-6 = 24 feet

Total Dynamic head (ft) = Static head + frictional losses

= 24 + 5 = 29 feet

3. **Determine the horsepower characteristics of the pump and motor:**

$$\text{Required pump HP} = \frac{(\text{flow in gal/min} \times (\text{total head in ft})}{3960}$$

$$= \frac{(3472)\ \ (29)}{3960}$$

$$= 25.4 \text{ HP}$$

$$\text{Required motor HP} = \frac{(\text{pump HP})}{(\text{pump efficiency})}$$

$$= \frac{25.4}{(0.85)}$$

$$= 29.9 \text{ HP}$$

$$\text{Consumed HP} = \frac{(\text{motor HP})}{(\text{motor efficiency})}$$

$$= \frac{29.9}{0.90}$$

$$= 33.2 \text{ HP}$$

4. **Compare the above computed head and power characteristics of the pump with those provided by the manufacturer. Check to ensure that the pump is not being forced to operate under conditions outside its rated design range.**

5. **Check motor horsepower by measuring current draw or amperage through each of the three phases of electrical supply to the motor using a "clamp around" current meter on each lead wire. The reading from each phase should be within 10 to 15 percent of each other, and should not be more than the amount listed on the nameplate of the motor.**

6. **Determine the horsepower of the pump and motor from the current readings taken above.**

$$\text{Current (amps)} = \frac{(\text{amps in phase 1} + \text{phase 2} + \text{phase 3})}{3}$$

$$= \text{use 40 amps}$$

$$\text{Motor HP} = (\text{Amps}) \times (\text{volts}) \times (1.9)/(1000)$$

$$= (40.0) \times (460) \times (1.9)/(1000)$$

$$= 36.0 \text{ HP}$$

These values of amperage were selected to give the correct horsepower. It is only an approximate method, and should only be used as a rough check.

Control Considerations

A raw sewage pumping system essentially has no method of controlling its operation, because the system is designed to pump to the treatment facility headworks the volume of raw sewage that enters the wet well. The only control the operator has is the selection of the lead and lag pumps and manipulation of the automatic controls from the water level in the wet well that starts and stops the pumps. Frequently, especially in larger treatment facilities, the raw sewage pumping station has a variable pumping rate controller. This device, which can be anything from a special type of motor to varying the frequency of the current to some type of mechanical device, operates the pumps by sensing the level of the water in the wet well. Conditions that could affect the efficient operation of the pumping station should be monitored carefully. An example of this could be the build-up of debris on an influent screen or rack, which might cause surges of sewage into the wet well, with the resulting impact on the level sensors, which in turn causes the pumps to start and stop intermittently. Influent screens are recommended in raw sewage pumping stations to protect the pumps from abrasive materials and objects that could plug the suction line to the pumps. These screens should be cleaned regularly as is discussed in the next section.

Pumping stations have an important effect on the overall performance of the treatment plant, since the flow through the plant depends on the pump capacity. Intermittent pumping during periods of low flow and frequent changes in pumping rates can cause process upsets. As a result, it is desirable for the pump capacity and storage capacity to be designed so that frequent stops and starts of the lead pump are avoided, and changes in pumping rates are minimal.

Maintenance Considerations

In addition to the maintenance management program described in the Overall Plant Management Section, the following list covers maintenance items specific to pumping stations.

1. The spare parts inventory should include at least the following items: one set of each type of bearing, grease seals, all necessary gaskets for replacement of parts, one set of mechanical seals if used on the pump, and the washers for adjusting the position of the impeller.

2. Deteriorated concrete or expansion joints should be repaired.

3. Measures for control of sewer gas (hydrogen sulfide) odors in the wet well should be provided.

4. Wet well ventilation and odor control systems should be checked regularly for correct operation.

5. All pumps should be visually checked for misalignment of the drive shaft, for constant rotation speeds, and for any excessive vibrations.

6. Pumps should be checked for unusual operating sounds such as screeching which could indicate lack of lubrication, thumping which could indicate broken or loose components or sharp, quick pinging sounds (like gravel hitting a metalic surface) accompanied by pump vibration which could indicate cavitation.

7. Daily readings of pumping times should be recorded from elapsed time meters. This can be used as a check on the plant flow and also for scheduling maintenance work.

Records

There are no recommended sampling or laboratory tests on a pumping station unless the station includes a screening device. In this case, required procedures would be as described in the next section.

Daily operating records at the raw sewage pumping station should include:

1. The length of time that each pump operates, as recorded by the elapsed time meters.

2. The total energy (electrical power) consumed.

3. The total pumpage through the station as measured by a flow meter with a flow-indicator-recorder unit and chart drive, (frequently a totalizer is also included which simplifies pumpage computations).

4. A determination of the sewage pumped by each pump.

5. An estimate of the rate of wastewater pumped per kilowatt.

Laboratory Equipment

There is no specific laboratory equipment required for this unit operation.

Sampling Procedures

Wastewater sampling is not required at this location in a treatment facility. If screening devices are included as an integral part of the pumping station, then the sampling procedures and requirements are as described for the next section.

Sidestreams

There are no sidestreams associated with raw sewage pumping stations.

Process Checklist - Raw Sewage Pumping Stations

1. Name of pumping station ______________________________.
2. Location of pumping station (if not on plant site) ______________
   ____.
3. What are the design flows? ____________ gpm average; _________ gpm peak?
4. What are the actual flows? ____________ gpm average; _________ gpm peak?
5. Are all pumps operable? ( ) Yes ( ) No. If no, describe reason why not ______________________________
6. Are all control systems, ventilation fans and miscellaneous equipment operable? ( ) Yes ( ) No. If no, explain ______________________
   ____
7. Is the pump control system ( ) variable speed, ( ) constant speed?
8. If variable speed, type of controller ______________________
9. In multiple pumping unit systems, is each unit operated ( ) about 15-20% apart, ( ) equally ( ) not alternated? Remotely monitored? ( ) Yes ( ) No
10. Does the facility have an alarm system? ( ) Yes ( ) No.
    Is it working? ( ) Yes ( ) No. Points monitored: wet well high water ____________, power failure ____________, aux. power running ____________, pump failure ____________.
11. Does the pumping station have a portable generator connection (for small systems)? ( ) Yes ( ) No.
    Is the portable generator operable? ( ) Yes ( ) No.
    Does it have sufficient capacity? ( ) Yes ( ) No
12. Does the pumping station have a portable pump connection (for small systems)? ( ) Yes ( ) No.
    Is the portable pump operable? ( ) Yes ( ) No
    Does it have sufficient capacity? ( ) Yes ( ) No
13. Does the pumping station have a bypass? ( ) Yes ( ) No
    If yes, can the bypass flow be disinfected? ( ) Yes ( ) No
14. Can the wet well be isolated into a minimum of two separate basins for maintenance? ( ) Yes ( ) No
15. If one wet well basin is down for maintenance, how many pumping units are operable? ____________________
16. Does the wet well design provide for equal division of flow to each of the pumping units? ( ) Yes ( ) No
17. Condition of the sump pump ( ) good ( ) fair ( ) poor ( ) N/A
18. Condition of the water seal system ( ) good ( ) fair ( ) poor ( ) N/A
19. Does the station have an adequate spare parts inventory? ( ) Yes ( ) No
20. Does the station have proper ventilation (both for safety and cooling of motors and motor control center)? ( ) Yes ( ) No. If no, what is the problem? ______________________________
21. Are there adequate safety provisions? ( ) Yes ( ) No. If no, what is the problem? ______________________________
22. How often is the pumping station checked? ( ) Daily ( ) Other________
23. What is the downtime of the pumping units? ____________________
24. What is frequency of scheduled maintenance?__________________/year
25. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ______________________________

26. If constant speed station, does it affect the operation of the treatment facility through sudden surges as each pumping unit is activated?
( ) Yes ( ) No

27. What is general condition of station (housekeeping)?
( ) good ( ) fair ( ) poor

28. What are the most common problems the operator has had with the pumping station? If problem with screens, use next section.
____
____
____
____

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2. RAW SEWAGE SCREENING

Process Description

The principal purpose of screening raw sewage flows is to remove large solids and trash, such as rags, sticks, lumber and other debris that could clog pumps and piping, and interfere with the proper operation of the treatment facility. Also, screens are sometimes used to provide some degree of wastewater treatment by incorporating significantly smaller openings for the passage of the sewage, thereby capturing larger volumes of influent solids. Screens are described in detail in Reference 1.

Typical Design Considerations

The bar screens are usually sized according to the velocity of the water passing through the screen, which has a recommended maximum velocity in the range of 2 to 2.5 fps for the maximum day flow. This value is related to two factors, the first being the significant headloss caused by higher velocities, especially if the bar screen is partially clogged. The second factor is the more practical aspect of raking the solids from the bars, which is made more difficult at higher velocities. Both these factors are less important when considering mechanical screens, although the recommended velocities still hold.

The fine screening devices, with openings less than 0.75 inches, are usually sized from manufacturers' literature and then provided with additional units for standby capacity. The standby units are put in service to allow cleaning of plugged screens. Typically, smaller openings allow less water through and require more width of screen. For example, the rotating screen allows only 12.25 gpm/inch width of screen through the .01 inch opening, but 80 gpm/inch width through the 0.1 inch openings.

Typical Performance Evaluation

The performance of the bar screens can be evaluated as described in Reference 1. A simple performance evaluation consists of visual inspection to see that debris has been cleared.

Process Control

The only control that an operator has over a bar screen, or trash rack, is the frequency of removal of screenings trapped by the screen. If screenings are not removed sufficiently frequently, water in the approach channel will back up resulting in surges of high flow after the screen has been cleaned. These conditions potentially could cause problems in following unit processes such as the grit chamber, primary clarifier and aeration basin.

The only control of the fine screening units is the frequency of cleaning and the number of individual units that are operational at one time. As more units are put into service, the individual loading rates will reduce and the removal efficiency will increase. The more units in service will also result in fewer surges of water to downstream processes.

Maintenance Considerations

In addition to the general maintenance management section presented in the overall plant management program the following items should be included for screen maintenance:

1. Spare parts inventory should include the following: one set of each type of bearings, seals and gaskets, one set of chain drives or cables for the mechanical bar screen or rotating drum, shear pins, and a spare set of rake teeth.
2. There should be a daily inspection of the screening assemblies to visually inspect the equipment for misalignment, excessive noise, excessive vibrations, unequal loading of equipment.
3. Daily readings of screening volumes from each screening device should be recorded. These can be used to check for unbalanced loadings on the screens, which could cause undue stress, requiring more frequent maintenance.

Records

There are no recommended sampling or laboratory tests required specifically for the screening devices. However, the channel in which the screen is located is normally the location of sample collection for influent data. This location is usually upstream of any recycle flows that may influence the concentrations of the various parameters measured.

Other operating records should include:

1. Volume of screenings captured per day on each screen.
2. An estimate of the unit volume of screenings captured per million gallons of flow.

Laboratory Equipment

There is no specific laboratory equipment required for this unit operation. The raw sewage is not normally sampled upstream of the screening device in order to avoid damage to the sampling mechanisms. However, "grab" samples are sometimes taken in order to correlate the volume of screenings captured to the percent reduction in total solids concentration across the screen. The following items could be used to determine solids content:

1. Balance
2. Drying Oven
3. Dessicator

Sampling Procedures

Although wastewater sampling is not routinely done on both sides of the screening device, "grab" samples should be taken occasionally to correlate the reduction in total solids concentration across the screen with the volume of screenings captured. The grab sample should be taken at the center of the channel, where the wastewater is normally homogeneous, and channel velocities are high.

Also, the screenings captured should be sampled occasionally to determine the volatile content and the moisture content. The volume of screenings captured can be determined by computing the volume of the containers into which they are placed and counting the number of containers filled each day.

Sidestreams

The only sidestream from the screening assemblies is the volume of screenings captured. The estimated unit volumes of screenings as a function of screen openings have already been shown. Generally screenings are incinerated or hauled to a landfill for disposal.

Process Checklist - Raw Sewage Screening

1. What are design flows__________ mgd avg. __________ mgd peak?
2. What are actual plant flows____________ mgd avg.________mgd peak?
3. Type of screen _________ Number _________ Capacity of each unit _________ mgd. Size of opening _____________.
4. Are the bar screens and associated equipment operable?( ) Yes ( )No If no, what is reason ____
5. What are dimensions of channels? ____
6. What is total daily volume of screenings?_________________________ cu ft
7. What is unit volume of screenings?____________________________cu feet/mg
8. Is screening ( ) manual ( ) mechanical?
9. Is there a bypass channel? ( ) with screen ( ) without screen.
10. Does influent channel design provide equal division of flow to each screen? ( ) Yes ( ) No
11. Do mechanical screens have adequate spare parts inventory? ( ) Yes ( ) No
12. If enclosed, is building properly ventilated? ( ) Yes ( ) No If no, what is problem? ____
13. Are there adequate safety provisions? ( ) Yes ( ) No If no, what is problem? ____
14. How often are screens checked? ( ) Daily ( ) Other ______________
15. What is downtime of the screens? ____
16. What is frequency of scheduled maintenance?________________________/Year
17. Is the maintenance program adequate? ( ) Yes ( ) No
18. What is general condition of the screening system? ( ) Good ( ) Fair ( ) Poor ( ) N/A
19. What are the most common problems the operator has had with the screening system? ____

____

____

____

____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

3. RAW SEWAGE SHREDDING AND GRINDING

Process Description

Raw sewage shredding and grinding devices are used to reduce the particle size of objects or debris in the influent wastewater. These devices may be installed with a screen directly in the wastewater flow or separately out of the wastewater flow, with the shredded particles returned to the flow downstream of the screen.

The shredding and grinding devices that are installed directly in the influent channel are termed comminutors or macerators and barminutors. The comminutor or macerator are similar devices that screen and grind simultaneously. The influent flow is channeled to and through these units. The debris collects against the screen, or outside drum, and the teeth which penetrate this screen cut up the solids. When the solids are reduced to the size of the screen or drum openings they pass through and on for additional treatment. The barminutor, is a comminuting device that incorporates revolving cutters that move up and down the upstream face of a bar screen, shredding and cutting whatever debris has accumulated against the screen. The shredding and grinding devices that are placed outside the wastewater flow receive debris from a mechanically cleaned bar screen. The screenings are transported to the cutting device, shredded and then allowed to fall back into the influent channel downstream of the bar screen. Detailed description of these devices are in Reference 1.

Typical Design Considerations

In-channel shredding and grinding devices are normally sized in terms of the flow rate that can pass through the unit. The greater the diameter of the unit, the greater the capacity. In addition, the velocity of approach of the wastewater should be limited to a range of 2 to 5 fps. Individual units have capacities ranging from 0.35 to 25.0 mgd and are capable of processing 650 to 5,200 lbs of solids, or debris, per hour.

Typical Peformance Evaluation

The inspector can evaluate the performance of shredders and grinders by observing or checking the following:

1. Observe the flow and build-up of debris against the screen and the cutting action of the unit. Plugging may occur if the debris are not properly cut up and flushed through the unit for further treatment downstream.

2. Check maintenance records for regular sharpening and adjustment of cutting edges or teeth.

3. Check the records for the frequency of maintenance as an indication of the amount or abrasive quality of debris being processed.

If the shredding and grinding units are located upstream of the grit chamber, abrasive action on the units would be more severe due to the presence of grit.

Process Control

Control of this unit operation is simply one of ensuring smooth functioning equipment and not permitting an accumulation of debris against the screens. If debris are not properly cut up, serious problems could potentially occur in downstream processes. For example, grit chambers could become clogged or subject to odors as a result of submerged debris and rags that escaped shredding. In addition, pumps and pipelines, especially suction lines, could become plugged and pump impellers damaged by poorly shredded material. Another example might be mechanical surface aerators becoming entangled with the rags and debris if not preceded by primary sedimentation. These problems can be essentially eliminated by proper maintenance of equipment.

Maintenance Considerations

In addition to the maintenance management programs discussed in the Overall Plant Management Section, shredding and grinding operations should include the following maintenance items.

1. Channel stop-logs checked for warping and possible replacement.
2. Channel sluice gates checked for operability.
3. Scheduled replacement of barminutor cables or chains.
4. Scheduled maintenance and sharpening of cutter teeth.
5. Spare parts should include the following: cutting teeth, shear bars, cables, rotative barminutor cutting edge, shear pins and drive chains.

Records

Operating records should include:

1. Raw sewage flow per influent channel.
2. Energy usage for each unit.

Laboratory Equipment

There are no specific laboratory equipment items required for this unit process.

Sampling Procedures

It is sometimes desirable to determine the total solids content of wastewater after shredding and grinding. These tests are usually accomplished on grab samples. The sample should be collected from a point in the channel where the wastewater is well mixed and relatively homogeneous and the velocities are high.

Sidestreams

There are no sidestreams associated with raw sewage shredding and grinding.

Process Checklist - Raw Sewage Shredding and Grinding

1. What is the actual flow ________ mgd average, ________ mgd peak?
2. How many shredding and grinding units are there ______; What type or make?____
3. What is the capacity of each unit ________ mgd?
4. If multiple units are used, is the flow evenly distributed?
( ) Yes ( ) No
5. Is shredding and grinding unit operable? ( ) Yes ( ) No
6. What are dimensions of channels?____________
7. Is there a bypass channel? ( ) Yes ( ) No
8. If units enclosed, is ventilation system operable? ( ) Yes ( ) No
If no, what is the problem? ________________________________
9. What is general condition of the shredding and grinding facilities?
( ) Good ( ) Fair ( ) Poor
10. Are proper safety precautions used? ( ) Yes ( ) No
11. Is there an alarm system for equipment failures or overloads?
( ) Yes ( ) No
12. How often are units checked? ____________________
13. What is downtime of the units? ____________________
14. Does the sampling program meet the recommendations? ( ) Yes ( ) No
15. Are the operating records adequate? ( ) Yes ( ) No
16. What is frequency of scheduled maintenance? ____________________
17. Is maintenance program adequate? ____________
18. What spare parts are stocked? ____________________________
____
____
19. What are the most common problems the operator has had with the process?
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).
3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).
4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).
5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).
6. State of Virginia O&M inspection form.

4. GRIT REMOVAL

Process Description

Grit removal facilities are designed to allow the settling out of this material. Grit includes sand and gravel, cinders, coffee grounds, small stones, cigarette filter tips and other large-sized materials. Grit removal is an important process for several reasons: (1) To prevent cementing effects at the bottom of sludge digesters and primary sedimentation tanks; (2) to reduce the potential for clogging of pipes and sludge hoppers; (3) to protect moving mechanical equipment and pumps from unnecessary wear and abrasion; (4) to reduce accumulations of materials in aeration tanks and sludge digesters which would result in a loss of usable volume; and (5) to reduce accumulations at the bases of mechanical screens.

Grit removal equipment can be velocity controlled, aerated, or of the constant head type, and the tanks can be rectangular, square or round in shape. Details of these systems can be found in Reference 1.

Grit handling facilities normally include facilities to wash or classify the grit in order to reduce the organic content in the grit. The grit washer consists of screw or rake mechanisms. To ensure a low volatile content in the grit, sufficient wash or dilution water is required. Grit washing is performed at the lower end of a grit classifier, which is a device that separates the organic material from the grit by a upflow water movement. The dewatered grit falls into containers for removal to a sanitary landfill for disposal.

For installations having a large percentage of organic material, a cyclone type grit classifier is used ahead of the grit washer. Cyclone degritters use centrifugal force to separate the grit from the wastewater in conically shaped units.

Typical Design Considerations

The velocity controlled systems limit the velocity in the rectangular channels to a maximum of 1 foot per second (fps). This velocity is low enough to allow the grit to settle but fast enough to maintain a majority of the organic material in suspension. The aerated grit chambers are normally sized on the basis of both detention time and volume of air. Typically, the detention time is in the range of 2 to 5 minutes and the air flow is in the range of 0.04 to 0.06 cu ft/gallon of wastewater. The constant head type of system is normally designed using an overflow rate of 15,000 gallons per day per square foot and a 1 minute detention time at peak day flows.

Typical Performance Evaluation

Grit removal facilities can be evaluated by comparing the amount of grit captured to typical values that have been recorded at other facilities. The volume of grit capture is directly related to whether the collection system is combined or separate or some combination of these. If the system is combined or partially combined, the amount of grit collected would be greater than for separate systems.

The performance of the grit washer or classifying system can be evaluated against the volatile content of the grit. The volatile content of grit measured prior to classification would be in the range of 10 to 70 percent, with a predominant range in values close to 30 to 50 percent. However, after washing and classifying the grit, the organic content should be less than 5 percent for the majority of the time and always less than 10 percent.

Process Control

The only control considerations for velocity-controlled grit systems are the speed of the scraper mechanism, and the frequency of operation of the scrapers. The scrapers should operate at a slow speed to minimize turbulent conditions and at frequent intervals to avoid excessive grit accumulations in the channel. The grit conveyance system to the grit classifier should have sufficient capacity to remove the grit from the collecting hopper. Improper speed control could result in damage to equipment due to grit packing in the basin if the speed is too slow, or too much water pumped and turbulent conditions if the speed is too fast.

In the aerated grit removal systems, the operator controls the air supply to the tank. The air rate must be adjusted so that the spiral roll velocity is low enough for grit to settle out of suspension but fast enough to maintain organics in suspension.

The constant head grit removal system requires that the influent flow be evenly distributed across the inlet side of the unit, and flow with equal velocity to the outlet weir. The grit collected by the scraper mechanism must be removed at a rate that will avoid build-up of grit in the basin.

The grit washer or classifier mechanisms should be operated so as to remove all the organic material as measured by the volatile content of the material. The control feature in the washer is the adjustable weir and rate of flow of the wash water. The efficiency of the cyclone device, as described, can be altered by changing the inlet and outlet orifices of the unit. Poorly washed grit removal can result in a high volatile solids content and severe odor nuisances can then develop.

Maintenance Considerations

Maintenance programs for grit removal systems should include the following items:

1. Spare parts inventory should include the following: flights and drive chains, turntable gears, and motors, wear shoes, sprockets, wall brackets, chain pins, shear pins, bearings, seals and gaskets, buckets, screw conveyor, impellers, air diffusers.
2. Record of broken or damaged guide vanes replaced in the case of a detritor.
3. Replacement of damaged scraper flights.

4. Replacement of broken, loose or damaged air piping or diffusers.

5. Chain tensions adjusted regularly on equipment using chains.

6. Daily inspection of the grit to check for odor which would indicate high organic content in the grit.

7. Daily readings of grit quantities from each grit chamber are recorded. These can be used to check for unbalanced loadings which might cause more frequent maintenance.

Records

The recommended sampling and laboratory tests are shown in Figure 4-1 for the grit removal system and in Figure 4-2 for the grit washer or classifier. Similar tests could be performed on the cyclone grit concentrator.

Other operating records should include the following:

1. Raw sewage influent flow.

2. Amount of grit collected per day.

3. Volatile content of grit.

4. Moisture content of grit.

5. Frequency and duration of grit raking mechanism for velocity controlled facilities.

6. Air flow per million gallons for the aerated grit chamber.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the grit removal system:

1. Analytical balance

2. Clinical centrifuge with graduated tubes

3. Drying oven

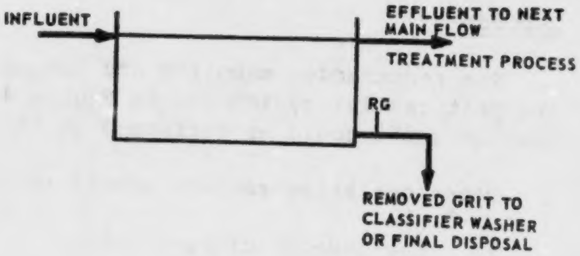
The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TOTAL SOLIDS	ALL	2/W	RG	G	P^{1}H
	TOTAL VOLATILE SOLIDS	ALL	2/W	RG	G	P^{1}H
OPTIONAL						

PRETREATMENT

GRIT REMOVAL


INFLUENT
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
RG
REMOVED GRIT TO CLASSIFIER WASHER OR FINAL DISPOSAL

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

RG = REMOVED GRIT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. AERATED TYPE ONLY

Figure 4-1

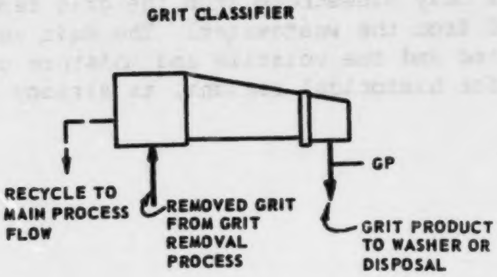
ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

PRETREATMENT

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	2/W	GP	G	H
TOTAL VOLATILE SOLIDS	ALL	2/W	GP	G	H


GRIT CLASSIFIER
GP
RECYCLE TO MAIN PROCESS FLOW
REMOVED GRIT FROM GRIT REMOVAL PROCESS
GRIT PRODUCT TO WASHER OR DISPOSAL

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

GP = GRIT PRODUCT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 4-2

Sampling Procedures

Samples should be collected from the grit container after washing and dewatering of the captured grit. The samples are normally grab samples, but should be representative of the grit collected and not taken at times of peak flows or low flows. The sample container should be clean to avoid incorrect results.

Sidestreams

The only sidestream from the grit removal facility is the volume of grit removed from the wastewater. The unit volumes (cu ft/mil. gal.) should be estimated and the volatile and moisture content of the grit should be determined for historical reasons, as already described.

Process Checklist - Grit Removal

1. What is design flow __________ mgd avg. __________ mgd peak?
2. What is actual plant flow __________ mgd avg?
3. Type of grit removal system __________, Number __________ and capacity of each unit __________ mgd, based on what criteria ____________________?
4. Is all equipment operable? ( ) Yes ( ) No If no, what is reason ______________________________
5. What are the dimensions of unit?____________________
6. What is daily volume of grit?__________ cu feet
7. What is unit volume of grit?__________ cu feet/mg
8. Is operation of grit collection equipment? ( ) Manual, ( ) time clock ( ) continuous duty.
9. Is there a bypass channel? ( ) Yes ( ) No
10. Does influent channel design provide equal division of flows to each grit unit? ( ) Yes ( ) No
11. Do grit collection mechanisms have adequate spare parts inventory? ( ) Yes ( ) No
12. Is the grit washer housing properly ventilated? ( ) Yes ( ) No. If no, what is problem? ______________________________
13. Are there adequate safety provisions? ( ) Yes ( ) No. If no, what is problem?______________________________
14. How often are grit facilities checked? ( ) Daily ( ) Other __________
15. What is frequency of scheduled maintenance?____________________/Year
16. Is the maintenance program adequate? ( ) Yes ( ) No
17. What are the most common problems the operator has had with the grit removal facility? ______________________________
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

7. Okun, D.A., et al, Sewage Treatment Plant Design, ASCE Manual of Engineering Practice, No. 36, 1959.

5. PRIMARY SEDIMENTATION

Process Description

Primary sedimentation basins or clarifiers are tanks used to remove suspended solids (SS) which will settle from the wastewater.

The main objectives of primary sedimentation basins are:

1. Remove settleable solids.
2. Remove floatable solids.

Sedimentation basins may be square, rectangular or circular in shape. In rectangular tanks, the wastewater flows from one end to the other and the settled sludge is moved to a hopper at one end, either by scrapers called "flights" set on parallel chains, or by a single bottom scraper set on a traveling bridge. Floating materials, such as grease and oil, are collected by a surface skimmer and then removed from the tank.

In circular tanks, the wastewater usually enters in the middle and flows toward the outside edge. Settled sludge is pushed to a hopper that is in the middle of the tank bottom. Floating material is removed by a surface skimmer connected to the sludge collector. Square sedimentation basins are basically the same as circular except corner mechanisms are added to sludge collectors and skimmers.

Typical Design Considerations

The most important loading factor is the rate of flow through the sedimentation basin. This factor is expressed in terms of gallons per day per square foot of surface area of the tank. The factor is called the "surface overflow rate" or "hydraulic loading rate." It is calculated as shown in the following example.

1. Determine basin shape and dimensions. The plant construction drawings and specifications include this information.

   Shape = circular
   Diameter, dia. = 100 ft
   Depth, D = 12 ft
   Basin area, $A = (\pi/4)\ \text{dia}^2$ = 7,850 sq ft
   Basin volume, gallons
   $V = A \times D \times 7.48$ = 704,616 gal

2. Determine total basin flow from plant records.*

   Daily Average: 6 mgd
   Peak Hour: 9.5 mgd

---

*If sidestreams (e.g. digester supernatant) are returned to the headworks then they should be added to the influent flow.

3. Calculate hydraulic surface loading rate (both daily average and peak hour) for clarifier.

$$\text{Hydraulic Surface Loading Rate} = \frac{\text{flow in gal/day}}{\text{surface area in sq ft}}$$

$$\text{Daily Average Loading Rate} = \frac{6{,}000{,}000}{7{,}850} = 764 \text{ gpd/sq ft}$$

$$\text{Peak Hour Loading Rate} = \frac{9{,}500{,}000}{7{,}850} = 1{,}210 \text{ gpd/sq ft}$$

The detention time of sedimentation basins is also often calculated. An example calculation for the same clarifier follows:

$$\text{Detention Time} = \frac{(\text{volume in gal}) \times 24 \text{ hr/day} \times 60 \text{ min/hr}}{\text{flow in gal/day}}$$

$$= \frac{704{,}616 \times 24 \times 60}{6{,}000{,}000}$$

$$= 169 \text{ minutes}$$

Typical design criteria are:

	Typical Design
Average daily hydraulic loading, gpd/sq ft	600 - 1,000
Peak hour hydraulic loading, gpd/sq ft	1,200 - 2,500
Detention Time, min	90 - 150

Typical Performance Evaluation

Primary sedimentation basins are designed to remove 100% of the settleable solids. In most wastewaters, this corresponds to about 65% removal of the raw wastewater suspended solids.

A number of factors affect the performance of primary sedimentation basin, including the following:

1. The surface overflow rate.

2. Wastewater characteristics (wastewater strength, freshness, and temperature; types and amount of industrial waste; and the density, shapes, and sizes of particles).

3. Pretreatment operations (carryover of grit and screenings).

4. Nature and amount of any in-plant wastes recycled ahead of the primary clarifier.

Figure 5-1 shows how much BOD and suspended solids are typically removed from wastewater in a primary sedimentation basin using the ratio of actual to design flow. The figure shows a design overflow rate of 800 gpd/sq ft. Because of the fixed size of the tank, the overflow flow rate and detention time will change with flow, resulting in different removal efficiencies.

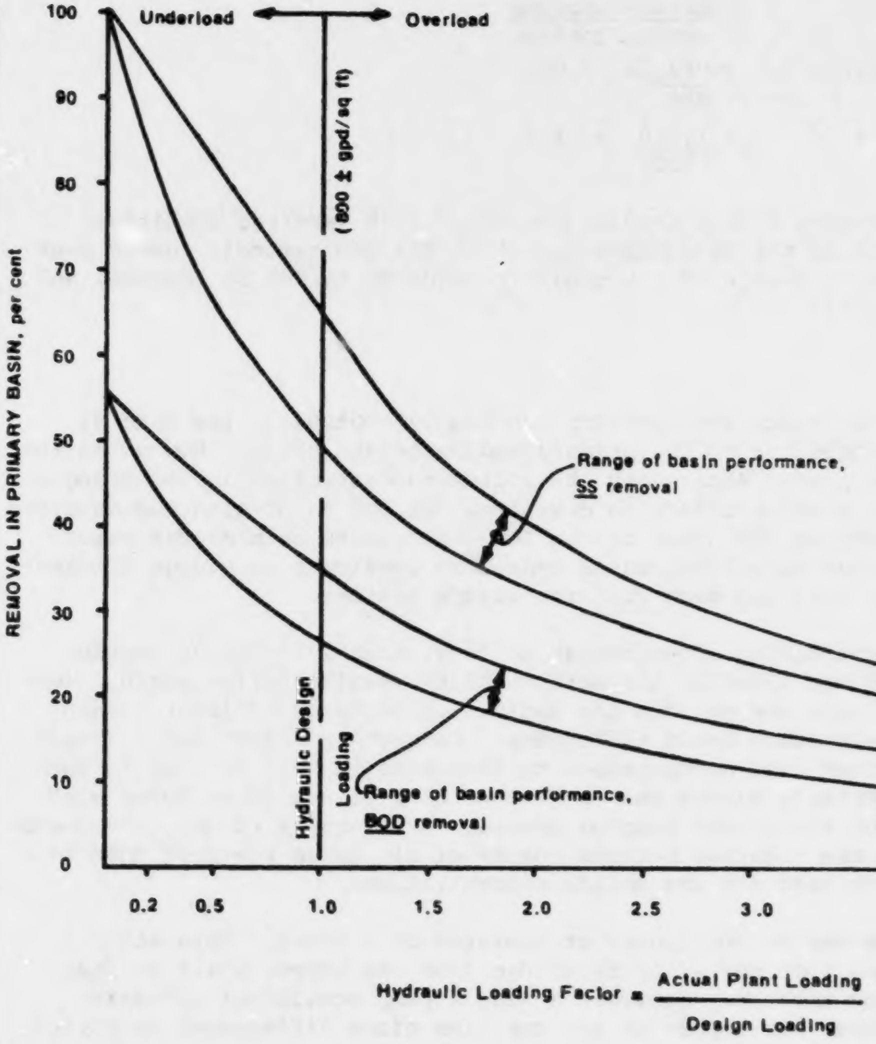


Figure 5-1. Estimated removals of suspended solids and BOD in primary basins at various hydraulic loadings.

Using the same example sedimentation basin and Figure 5-1, the expected performance would be:

Loading factor $= \frac{\text{actual loading}}{\text{design loading}}$

Average conditions $= \frac{764}{800} = 0.96$

Peak conditions $= \frac{1{,}210}{800} = 1.5$

Referring to Figure 5-1, a loading factor of 0.96 (average condition) should result in 50 to 65% SS removal and 25 to 35% BOD removal. Under peak loading conditions, a factor of 1.5 should provide 40 to 50% SS removal, and 20 to 30% BOD removal.

Process Control

The major factor which the operator can easily control is the rate at which sludge is pumped out of the primary sedimentation basin. How often and how long sludge is pumped determines the solids concentration in the sludge. This, in turn, has a major effect on downstream sludge thickening and dewatering processes. Pumping too often or too long will cause thin sludge which lowers plant digester capacity; causes hydraulic overloads to sludge thickening processes; and uses too much fuel for sludge heating.

If sludge is not pumped often enough or long enough, it can go septic, causing odors, and may float to the surface of the sedimentation basin. Some of the floating sludge may go into the sedimentation basin effluent causing a reduction in sedimentation basin efficiency. Laboratory "spin" tests (small centrifuge) are often used by operators to determine when it is time to pump out the sludge. Primary sludge concentrations of 5-7% are often found with proper operation of the sludge pumping system. By frequent checks, the operator can determine the relation between volume of sludge in the test tube at the end of the spin test and the solids concentrations.

Sludge pumping may be continuous or operated on a timer. When several pumps are used, one pump may withdraw sludge from one hopper while another pump withdraws from another. However, a single pump should not withdraw sludge from more than one hopper at any one time since differences in piping friction and sludge characteristics can cause more sludge to be withdrawn from one hopper than from the other. Pumping should be done often and for short periods rather than less often for longer periods.

In very small treatment plants with operating personnel on duty only part of the time, sludge is sometimes pumped only once or twice a day.

A properly operated primary sedimentation basin will do much to provide smooth and efficient operation of downstream unit processes. For example, improper control of primary tank operations may cause solids and BOD overloading problems and result in poor effluent quality.

For good operation, sedimentation basin flows must be distributed evenly among all available tanks. Uneven flows to the various tanks result in a poor overall reduction of SS and BOD.

As with most unit processes, primary sedimentation is related to other plant processes. Some of the factors that will affect settling tank operation include recycling of waste sludge and supernatant, and carryover of grit and screenings from pretreatment.

Maintenance Considerations

Maintenance considerations in addition to those discussed for Overall Plant Management are:

1. Scraper flight inspection and maintenance schedule.
2. Periodic chain tension adjustment (in rectangular basins) so that there is no chattering sound.
3. Spare parts inventory should contain the following: flights and drive chains for rectangular basins, turntable gears and motors for circular basins, wear shoes, sprockets, wall brackets, chain pins, and shear pins.

Records

Recommended sampling and laboratory tests are shown in Figure 5-2.

Other operating records should include:

1. Raw sewage influent flow.
2. Volume of recycle flows to primary clarifier.
3. Amount of sludge and scum pumped per day.
4. Frequency and duration of operation of sludge pumps.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor primary sedimentation:

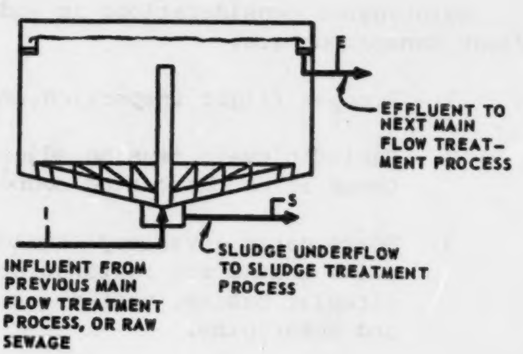
1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Imhoff Cones

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

PRIMARY CLARIFICATION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I E	24C	H
	SUSPENDED SOLIDS	ALL	3/W	I E	24C	H
	SETTLEABLE SOLIDS	ALL	3/W	I E	G	H
	TOTAL SOLIDS	<1	3/W	S	G	P
	SLUDGE VOLUME LAB CENTRIFUGE	1	3/D	S	G	P
	TOTAL SOLIDS	1	1/W	S	G	P
OPTIONAL	COD	15	1/W	I E	24C	H
	VOLATILE SUSPENDED SOLIDS	5	3/W	I E	24C	H


E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
S
I
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS, OR RAW SEWAGE
SLUDGE UNDERFLOW TO SLUDGE TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
S SLUDGE UNDERFLOW

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 5-2

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed such as at the center of the channel of flow where velocities are high. Raw wastewater samples should be collected after screening and grit removal. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The only sidestream from the primary sedimentation process is the sludge pumped from the sedimentation basin. When pumping 5 to 7% sludge, the volume of sludge pumped for most wastewaters from municipalities will be about 1,500 - 2,000 gallons per day per million gallons treated. If 3% solids are pumped, the volume would jump to 3,300 gallons. This shows the importance of not pumping thin sludges.

Process Checklist - Primary Sedimentation

1. What is the volume of influent flow ________________gallons/day average?
2. What is the design flow __________ gallons/day average? What are the dimensions of the sedimentation basin __________________________?
3. How much sludge is pumped _____________gallons/day?
4. What is the solids concentration in the sludge ___________%?
5. Are there settleable solids in the effluent ____________ml/liter?
6. Is sludge pumping ( ) manual ( ) automatic?
7. How often do sludge pumps run _____________minutes/hour?
8. Frequency of maintenance inspections by plant personnel __________/year.
9. Is maintenance program adequate? ( ) Yes ( ) No
10. Does the influent baffle system accomplish its purpose? ( ) Yes ( ) No
11. Is the scum collection system operating properly? ( ) Yes ( ) No
12. Is the sludge collection system operating properly? ( ) Yes ( ) No
13. Does the sludge collection system show any signs of mechanical failure? ( ) Yes ( ) No
14. Does the tank surface indicate improper sludge withdrawal? (i.e. excessive floating solids, gas. . .) ( ) Yes ( ) No
15. Is there an excessive accumulation of scum? ( ) Yes ( ) No
16. Does the effluent baffle system accomplish its purpose? ( ) Yes ( ) No
17. Are the effluent weirs level? ( ) Yes ( ) No
18. Are the effluent weirs kept clean? ( ) Yes ( ) No
19. If multiple units are used, is the flow distributed evenly? ( ) Yes ( ) No
20. Are proper safety precautions used? ( ) Yes ( ) No
21. Does the unit show signs of short circuiting and/or overloads? ( ) Yes ( ) No
22. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
23. Does the sampling program meet the recommendations? ( ) Yes ( ) No
24. Are operating records adequate? ( ) Yes ( ) No
25. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
26. What spare parts are stocked? ____
    ____
    ____
27. What are the most common problems the operator has had with the process?
    ____
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

6. ACTIVATED SLUDGE

Process Description

The activated sludge treatment process is used to convert nonsettleable and dissolved organic contaminants, such as BOD, into biological floc, which can then be removed from the wastewater by settling. Conversion of organics into biological solids for easier removal is the prime reason for using the activated sludge process and forms the basis for an understanding of the process.

The activated sludge process is a treatment system in which the incoming wastewater is mixed with existing biological floc (microorganisms or activated sludge) in an aeration basin. The biological floc is separated from the liquid in a sedimentation tank which follows the aeration basin. Part of the separated biological floc is returned to the aeration basin to provide good treatment of the wastewater and part is wasted (see flow diagram on Figure 6-1). A detailed description of the activated sludge process can be found in Reference 1.

Typical Design Considerations

Typical design criteria for variations of the activated sludge process are presented in Reference 1 and repeated in Table 6-1. The values represent the ranges that are normally found in operating systems. Many design methods and considerations have been proposed over the years. Descriptions of these methods are not repeated here.

Typical Performance Evaluation

The activated sludge process can convert nearly all influent soluble organic matter into solids. Good treatment includes removing these solids in a secondary clarifier. The performance of plain sedimentation of biological sludge is not easily predicted. When there are large amounts of solids there can be poor settling and solids carryover. When properly designed and operated, an activated sludge plant should consistently produce effluent suspended solids and BOD of 20-30 mg/l or less.

Many small extended aeration plants do not have good sludge wasting practices and frequently discharge effluent with high solids concentrations. The oxidation ditch extended aeration process has performed well and reliably when solids are managed properly.

The activated sludge process can be evaluated by using plant operational data to check the operating conditions against values given in the previous section. For a better understanding of how to evaluate plant performance, certain terms are defined in Reference 1. Additional information can be found in the references listed at the end of the chapter.

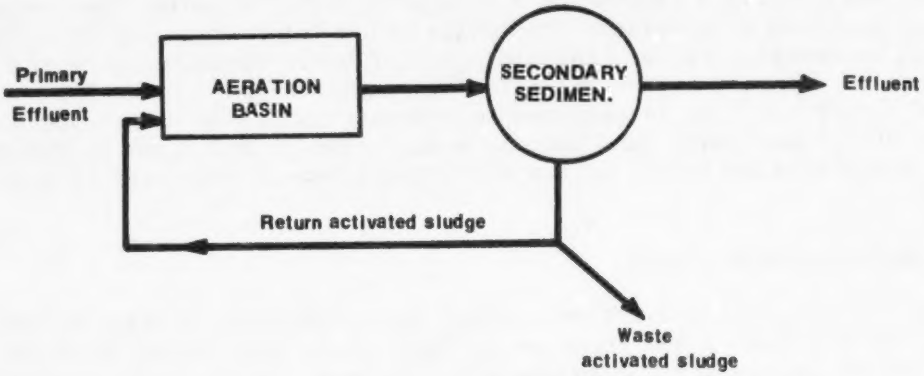

Primary
Effluent
AERATION
BASIN
SECONDARY
SEDIMEN.
Effluent
Return activated sludge
Waste
activated sludge

Figure 6-1. Activated sludge flow diagram.

TABLE 6-1. TYPICAL ACTIVATED SLUDGE DESIGN PARAMETERS(1)

Process Modification	Flow regime	Sludge retention time (days)	Food to microorganism ratio-#BOD_5/ MLVSS/day	Aerator loading #BOD_5/ 1,000 ft^3 tank volume	Mixed liquor suspended solids(mg/l)	Detention time (hr)	Recirculation ratio
Conventional	Plug	5-15	0.2 -0.4	30-40	1500-3000	4-8	0.25-0.75
Complete mix	Complete mix	3-10	0.2 -0.6	50-120	3000-6000	4-6	0.25-1.0
Step aeration	Plug	5-15	0.2 -0.4	40-60	2000-3500	3-6	0.25-0.75
Contact stabilization	Plug	5-15	0.2 -0.6	30-75	1000-4000(2) 4000-10000(3)	0.5-1.5(3)	0.5 -1.5
Extended aeration	Complete mix	20-30	0.05-0.15	10-15	2000-6000	24	0.5 -2.0
Pure oxygen systems	Complete mix reactors in series	8-20	0.25-1.0	100-250	4000-8000	1-4	0.25-0.5

(1) Values given are for organic removals only; no nitrification

(2) Contact unit

(3) Stabilization tank

Based on operating data from plants in the United States, Table 6-2 has been developed. This table shows several values that are actually being used in the operation of the plants and the range of effluent qualities obtained. Note that the average aeration time of 3.3 hours is lower than the currently accepted values presented in Table 6-1.

Process Control

The activated sludge process has many controls that can be used to change the operation of the system. A brief description of the major control variables is given here.

Dissolved Oxygen in Aeration Tank--

With conventional aeration systems, dissolved oxygen (DO) in the mixed liquor should be maintained in the 1-3 mg/l range with 2 mg/l being the desirable minimum. With pure oxygen systems, higher levels of DO are maintained, with minimum levels being 2-3 mg/l.

Return Activated Sludge Flow Rate--

To properly operate the activated sludge process, a good settling mixed liquor must be achieved and maintained. The MLSS are settled in a clarifier, and then returned to the aeration tank as the Return Activated Sludge (RAS). The RAS makes it possible for the microorganisms to be in the treatment system longer than the flowing wastewater. For conventional activated sludge operations, the RAS flow is generally about 25 to 75% of the incoming wastewater flow. Changes in the activated sludge quality will require different RAS flow rates due to settling characteristics of the sludge.

Sludge Blanket Depth in Secondary Clarifier--

Checking the depth of the sludge blanket in the clarifier is the most direct method for determining the RAS flow rate. The depth of the sludge blanket may be found by several types of devices. Some are commercially available while others must be made by the operator.

Waste Activated Sludge Flow Rate--

The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of BOD. When the microorganisms remove BOD from wastewater, the amount of activated sludge increases. The rate at which these microorganisms grow is called the "growth rate" and is defined as the increase in the amount of activated sludge that takes place in one day. The objective of sludge wasting is to remove just that amount of microorganisms that grow each day. This allows the total amount of activated sludge in the process to remain nearly constant. This condition is called "steady-state" which is a desirable condition for operation.

Wasting of the activated sludge is normally done by removing a portion of the RAS flow. The waste activated sludge is either pumped to thickening facilities and then to a digester, or to the primary clarifiers where it is pumped to a digester with the raw sludge.

TABLE 6-2. SUMMARY OF OPERATING DATA - ACTIVATED SLUDGE PLANTS

Activated sludge Process	Influent flow, mgd	Sludge recycle, %	Aeration time, hrs	BOD, mg/l		% Removal
				Sec. inf.	Sec. eff.	
Conventional	3.9-288	16-52	5.7-10.0	92-256	6-36	77-96
average			7.8	152	15	91
Step aeration	12.8-183	16-92	2.5-8.4	74-140	3-18	84-94
average			4.3	116	12	89
Complete mix	0.29-9.8	21-200	1.8-5.0	80-350	6-37	76-98
average			3.3	199	19	89
Pure oxygen	0.10-35.4	14-56	0.8-3.3	84-304	9-23	88-97
			2.1	194	16	91

An alternate method for wasting sludge is from the mixed liquor in the aeration tank. There is much higher concentration of suspended matter in the RAS than there is in the mixed liquor. When wasting from the mixed liquor is practiced, larger sludge handling facilities may be required because of the greater liquid volumes involved.

Microscopic Examination--

Microscopic examination of the MLSS can be used to evaluate the activated sludge process. The presence of various microorganisms within the sludge floc can rapidly indicate good or poor treatment. Protozoa play an important role in clarifying the wastewater and act as indicators of the degree of treatment. The protozoa eat the bacteria and help produce a clear effluent. The presence of rotifers is also an indicator of effluent stability. The presence of filamentous organisms and a limited number of protozoa is characteristic of a poor quality activated sludge. This condition is commonly associated with a sludge that settles poorly.

Process Control References--

There have been many publications on the control of activated sludge systems. It is not practical to summarize all of this information in this manual. The evaluator should read the following references (from which portions of this section were drawn) for detailed information on process control:

> "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities", U.S. EPA, Municipal Operations Branch, Office of Water Programs, Washington, D.C. 20460 (March, 1977)
>
> "Design Procedures for Dissolved Oxygen Control of Activated Sludge Processes", U.S. EPA, Office of Research and Development, Cincinnati, Ohio 45268
>
> West, Alfred W., Operational Control Procedures for the Activated Sludge Process, Parts I, II, IIIA, IIIB, IV and V, U.S. EPA Office of Enforcement and General Counsel, 1975.

Maintenance Considerations

Maintenance considerations specific to activated sludge systems are listed below. The general maintenance management discussion in the Overall Plant Management Section also should be reviewed.

1. The spare parts inventory should contain at least the following parts: one set of each type of bearing, V-belt or chain drives for each system, grease seals, all necessary gaskets for replacement of parts, one set each of mechanical seals, washers or sheaves to allow for adjustment of impellers.

2. Inspection each shift of the aeration basin and oxygen transfer facilities (blowers, mechanical aerators, oxygen generation equipment) for signs of equipment misalignment, constant rotative speeds, any excessive vibrations, excessive noise from the blowers or compressors.

3. Schedule rotation of mechanical equipment to ensure even wear.

4. Mechanical aerators regularly overhauled and the floats and steel parts painted and adjusted as necessary to achieve the correct oxygenation rate.

5. Daily readings of pumping times (RAS and WAS) recorded from elapsed time meters. This can be used as a check on plant operations and also for scheduling maintenance work.

6. Daily readings of blower operating times and/or air flow rates recorded. These can be used for plant operations and also for scheduling regular maintenance work. Similar procedures should be followed for mechanical aerators and air compressors for the oxygen generating system.

7. Utilization rate of oxygen monitored in order to optimize treatment efficiency and minimize energy consumption. Also check the cfm of air per lb of BOD removed to ensure it is within recommended ranges.

8. Motor operating times scheduled so that maintenance downtimes do not occur simultaneously.

9. Flow rate per kilowatt hour determined for the blowers, mechanical aerators or oxygen system. A deviation from an average value is a good indication of efficiency and changing conditions that might require maintenance.

10. Periodic tests run on each pump or blower to ensure that it operates at the same conditions as when it was supplied.

11. All non-operating equipment, such as basin dewatering pumps, sluice gates and weir gates or standby electric generators, tested at least once per month.

12. All underwater instrumentation checked and cleaned weekly. An example would be the DO probes or MLSS analyzers.

13. All scum and sludge lines flushed regularly.

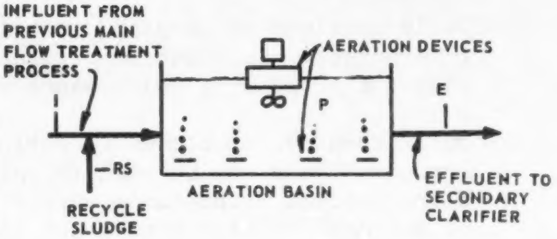
Records

Recommended sampling and laboratory tests are shown on Figure 6-2.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

ACTIVATED SLUDGE


INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
I
AERATION DEVICES
P
E
RS
RECYCLE SLUDGE
AERATION BASIN
EFFLUENT TO SECONDARY CLARIFIER

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	P
	SUSPENDED SOLIDS	ALL	5/W	E	24C	P
	SETTLEABILITY	ALL	5/W	E	G	P
	pH	ALL	5/W	P	G	P
	DO	ALL	5/W	P	G	P
	AIR INPUT[1]	ALL	R	B	R	H
	NH_3-N[2]	ALL	1/D	I[3]	24C	H
	ORG-N[2]	ALL	1/D	I[3]	24C	H
	NO_3-N[2]	ALL	1/D	I[3]	24C	H
	TOTAL-P[2]	ALL	3/W	I[3]	24C	H
	ORTHO-P[2]	ALL	3/W	I[3]	24C	H
	RAS	ALL	R	RS	R	P
	MICROSOPIC ANALYSIS	ALL	2/W	P	G	H
	NO_3-N	ALL	3/W	P	G	P
OPTIONAL	TOTAL SOLIDS	>1	3/W	E	24C	H
	TOTAL VOLATILE SOLIDS	>1	3/W	E	24C	H
	COD	>5	2/W	I	24C	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
P = PROCESS
B = BLOWER (INCLUDE WITH PROCESS TESTING)
RS = RECYCLE SLUDGE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. DIFFUSED AIR ONLY
2. TO BE RUN IF PROCESS IS DESIGNED TO CONTROL THIS PARAMETER
3. MAYBE RUN ON PLANT INFLUENT IF THIS IS INITIAL UNIT PROCESS FOLLOWING PRETREATMENT

Figure 6-2

Other operating records should include:

1. Raw sewage influent flow.
2. Return and waste activated sludge flows.
3. MLSS and MLVSS in the aeration basin and the return sludge line.
4. The unit volume of air or pure oxygen supplied per lb of BOD removed.
5. Frequency and duration of operation of the RAS and WAS pumps.
6. The total energy (electricity) consumed.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the activated sludge process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment
6. Wet chemistry equipment for monitoring ammonia conversion (nitrification) if this is required.

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as in the aeration basin close to the mixing device or air diffusers, or from the sludge lines after the sludge has been flowing for about a minute. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

There are no sidestreams associated with the aeration basin of the activated sludge process. The RAS and WAS are discussed in conjunction with the secondary sedimentation basin.

Process Checklist - Aeration Basin

1. What is actual plant flow __________ mgd avg. __________ mgd peak?
2. Type of activated sludge system (flow regime e.g. conventional) __________
3. Type of aeration system ________________ Number of units __________ and capacity of each unit ________________
4. Color ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
5. Odor ( ) septic ( ) Earthy ( ) None ( ) Other ________________
6. Foam ( ) light, crisp ( ) thick, dark ( ) heavy white ( ) Other __________
7. Are tank contents mixed thoroughly? ( ) Yes ( ) No
8. Are all diffusers or mech. aerators operating properly? ( ) Yes ( )No
9. Does mixing appear excessive? ( ) Yes ( ) No
10. Do there appear to be dead spots in aeration tank? ( ) Yes ( ) No If yes, at what location? ________________________________
11. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ________________________________
12. Are RAS pumps operating? ( ) Yes ( ) No. If no, what is the reason? ________________________________
13. Are there flow measurement devices for the RAS and WAS systems? ( ) Yes ( ) No. Are they operable ( ) Yes ( ) No
14. Does the aeration basin have a foam control system? ( ) Yes ( ) No Is it operable? ( ) Yes ( ) No. Is it operating: ( ) Yes ( ) No
15. Is the aeration tank area provided with adequate safety features (guardrails, nonskid surfaces, life preservers, lights)? ( ) Yes ( ) No
16. If multiple basins are operating, is the flow distributed equally? ( ) Yes ( ) No How is it distributed?____________________
17. Are the characteristics of the basin contents different in the various units? ( ) Yes ( ) No, If yes, describe ________________________________
18. What are the tank dimensions? ________________________________
19. Is operation of the system ( ) Manual ( ) Semi-Automatic ( ) Automatic ( ) Computer controlled ( ) Other ______________
20. Do mechanical equipment (blowers, air diffusers, mech. aerators, oxygen system, etc.) have adequate spare parts inventory? ( ) Yes ( ) No
21. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
22. How often are facilities checked? ( ) once per shift ( ) daily ( ) Other ______________
23. What is frequency of scheduled maintenance?____________________ ________________________________
24. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ________________________________
25. What is general condition of the activated sludge facilities? ( ) good ( ) fair ( ) poor
26. What are the most common problems the operator has had with the activated sludge system? ________________________________
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).
3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).
4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).
5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).
6. State of Virginia O&M inspection form.
7. Tsugita, R.A., et al, Process Control Manual for Aerobic Biological Wastewater Treatment Facilities, US EPA, Municipal Operation Branch, March 1977.
8. Flanagan, M.J. and Braken, B.D., Design Procedures for Dissolved Oxygen Control of Activated Sludges, US EPA, EPA 600/2-77-032, Office of Research and Development, June 1977.
9. Ettlich, W.F., A Comparison of Oxidation Ditch Plants to Competing Processes for Secondary and Advanced Treatment of Municipal Wastes, US EPA, 600/2-78-051, March 1978.

7. TRICKLING FILTERS

Process Description

Trickling filters consist of a bed of coarse material, either natural or synthetic, over which primary effluent is uniformly distributed. As the wastewater trickles through the media, dissolved organics and finely divided organic solids are oxidized. The effluent is collected in an underdrain system and either recycled through the filter or diverted to a secondary clarifier.

As the microorganisms utilize the organics and nutrients provided by the wastewater, the slime coating on the media thickens. This periodically sloughs (falls) off. Secondary sedimentation tanks are used to remove it from the wastewater flow. This sloughing activity removes stabilized material from the trickling filter and prevents clogging of the void spaces in the filter media.

Typical Design Considerations

Trickling filters are classified according to hydraulic and organic loadings given in Table 7-1. The low rate filter is generally a single stage system without recirculation. Intermediate rate filters are generally single stage with some recirculation. High rate filters generally have a two stage system with recycle to provide a relatively constant hydraulic loading. The super-high rate trickling filter uses plastic media. Plastic media is relatively light so it can be used for deep media beds. Higher hydraulic loading rates can be used with deep beds. The flow configurations suitable for super-high rate filters are similar to those for high rate units. There are many flow configurations for trickling filters. Details of these design considerations can be found in Reference 1.

TABLE 7-1. TRICKLING FILTER CLASSIFICATION

Trickling filter classification	Hydraulic loading, mgd/ac	Organic loading, lb BOD/1000 cu ft/day
Low rate	1 - 4	5 - 25
Intermediate rate	4 - 10*	15 - 30
High rate	10 - 40*	25 -300
Super-high rate	150*	up to 300

* including recirculation

Typical Performance Evaluation

Typical overall efficiency of a trickling filter treatment plant is about 80 to 85 percent removal of BOD and suspended solids for municipal wastewaters, or a concentration of about 30 mg/l of suspended solids and BOD in the final effluent. The actual effectiveness of the trickling filter process, however, depends on the following factors:

- Growth of biological organisms
- Raw wastewater concentration
- Dissolved oxygen
- Temperature
- pH and/or toxic conditions

The following will serve as an example of step-by-step procedures for evaluating the performance of trickling filters:

1. Define the design and operating mode of the trickling filter.
   Intermediate Rate Rock Media
   Depth, D = 8
   Diameter, dia = 200 ft
   Surface Area, $A = (\pi/4)\ \mathrm{dia}^2$ = 31,400 ft^2
   Volume, $V = A \times D$ = 251,200 ft^3
   Flow
      Raw wastewater = 3.5 mgd
      Recirculated = 3.5 mgd
      Total, Raw + Recirculated = 7.0 mgd
   BOD, influent to trickling filter = 170 mg/l
   BOD, clarifier effluent = 30 mg/l
   Temperature = $20^{\circ}\mathrm{C}$

2. Determine the combined efficiency of BOD removal for the trickling filter and secondary clarifier.

$$\%\ \text{BOD removal} = \frac{\text{BOD (primary effluent)} - \text{BOD (clarifier effluent)} \times 100}{\text{BOD (primary effluent)}}$$

$$= \frac{(170-30)}{170} \times 100$$

$$= 82\%$$

3. Determine the hydraulic loading rate for the filter.

$$\text{Hydraulic load} = \frac{\text{Total Flow in gpd}}{\text{Surface Area in ft}^2}$$

$$= \frac{7.0 \times 10^6\ \text{gpd}}{31{,}400\ \text{ft}^2}$$

$$= 223\ \text{gpd/ft}^2\ \ (9.71\ \text{mgd/ac})$$

As given in Table 7-1, this is within the typical range given for intermediate rate filters.

4. Determine the organic loading rate for the filter.

$$\text{Organic Load} = \frac{(\text{Flow in mgd}) \times (\text{BOD mg/l}) \times (8.34\ \text{lb/gal})}{(\text{Vol in ft}^3) - 1000}$$

$$= \frac{3.5 \times 170 \times 8.34 \times 1000}{251{,}200}$$

$$= 20\ \text{lb BOD/1000 cu ft}$$

This value falls within the range for organic loading of 15 to 30 lb BOD/1000 cu ft also given in Table 7-1.

5. Calculate the recirculation ratio for the trickling filter.

$$\text{Recirculation ratio} = \frac{\text{Recirculated flow, mgd}}{\text{Raw wastewater flow, mgd}}$$

$$= \frac{3.5}{3.5}$$

$$= 1/1$$

The recirculation ratio is important to the control and proper operation of a trickling filter. Although they are designed for a theoretical recirculation ratio, the actual day-to-day recycling of trickling filter effluent will depend on field conditions.

Process Control

The efficiency of treatment attained by trickling filter plants depends on the operation of the final settling tanks. It is essential that sludge be removed from the final settling tank before it rises to the surface and is carried out with the final effluent. The operation of final settling tanks is especially important in the case of high rate trickling filters. In this case, sludge becomes septic much faster than the sludge from standard rate filters; consequently, it should be removed more rapidly.

In intermediate and high rate trickling filters, recirculation ratios usually range from 0.5 to 4.0 with higher ratios considered to be economically unjustifiable. Common engineering practice is to design for ratios of 0.5 to 2.0. Trickling filters with synthetic media use recirculation as a means of maintaining a hydraulic loading (gpm/sq ft) which will maintain biological growth throughout the media depth.

For more detailed information on process control, the evaluator should read:

> "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities", U.S. EPA, Municipal Operations Branch, Office of Water Programs, Washington, D.C. 20460 (March, 1977)

Maintenance Considerations

In addition to the maintenance program discussion in the Overall Plant Management section, there are several maintenance considerations for trickling filters listed below.

1. The spare parts inventory should contain at least the following parts: one set of each type of bearing, grease seals, all necessary gaskets for replacement of parts, one set each of mechanical seals, washers or sheaves to allow for adjustment of impellers. Extra flow distribution nozzles should also be in stock.
2. Periodic check for deterioration of filter media or housing.
3. Inspect the towers and appurtenant facilities each shift. Recycle pumping and flow distributors should be checked daily and cleaned bi-annually.
4. Schedule overhaul of flow distributors with steel parts painted and adjusted as necessary to achieve the desired application rate.
5. Motor operating times scheduled so that maintenance downtimes do not occur simultaneously.
6. Periodic tests run on each pump to ensure that it operates at the same conditions as when it was supplied.
7. All non-operating equipment, such as standby electric generators, tested at least once per month.
8. Instrumentation immersed in water checked and cleaned weekly.
9. Regular cleaning of underflow and recycle lines.

Records

Recommended sampling and laboratory tests are shown in Figure 7-1.

Other operating records should include:

1. Raw sewage influent flow.
2. Recirculation flow and recirculation ratio.
3. DO should be analyzed periodically to verify adequate ventilation of the filter.
4. The total energy (electricity) consumed.

Laboratory Equipment

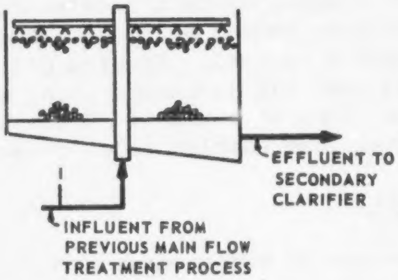
The laboratory should include the following minimum equipment in order to monitor the trickling filter process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

TRICKLING FILTER


I
EFFLUENT TO SECONDARY CLARIFIER
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	P
OPTIONAL	COD	>5	2/W	I	24C	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 7-1

3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be consulted for any detailed questions.

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as in the distribution line or from the sludge lines after the sludge has been flowing for about a minute. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that underflow from all areas of the filter is thoroughly mixed. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

There are no sidestreams associated with the trickling filter process itself. Solids production and disposal are discussed in Section 11.

Process Checklist - Trickling Filters

1. What is actual plant flow ________ mgd, average; _________mgd, peak?
2. What is recycle flow ___________ mgd? Is it _____________ constant, __________ intermittent?
3. What is filter classification _________ low, _________ intermediate, _________ high, _________ super-high?
4. What type of media is used?____
5. What is the depth of media?_______________ feet
6. Number of units ______________; Diameter of units _________________
7. Color ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other_______
8. Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ___________
9. Is there evidence of uneven flow distribution? ( ) Yes ( ) No
   Are any nozzles clogged? ( ) Yes ( ) No
10. Is there evidence of filter clogging such as ponding? ( ) Yes ( ) No. Icing? ( ) Yes ( ) No Other _________________
11. Is there evidence of filter flies? ( ) Yes ( ) No. Snails ( ) Yes ( ) No. Roaches ( ) Yes ( ) No. Other ___________
12. Is there grass or other vegetative material growing on the filter? ( ) Yes ( ) No Other _______________________
13. Are there flow measurement devices for the recirculation flow? ( ) Yes ( ) No. Are they operable? ( ) Yes ( ) No
14. Are the recirculation pumps operating? ( ) Yes ( ) No. If no, why? ____
    ____
15. Is the trickling filter area provided with adequate safety features (quardrails, nonskid surfaces, life lines, lights)? ( ) Yes ( ) No
16. If multiple filters are operating, is the flow distributed equally? ( ) Yes ( ) No. How is it distributed? ____________________
17. Are the characteristics of the filter contents different in the various units? ( ) Yes ( ) No. If yes, describe ____________________
    ____
18. Is operation of the system ( ) manual ( ) semi-automatic ( ) automatic ( ) computer controlled ( ) other _____________
19. Does mechanical equipment (flow distributors, pumps, etc) have adequate spare parts inventory? ( ) Yes ( ) No
20. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
21. How often are facilities checked? ( ) once per shift ( ) daily ( ) other ___________________________
22. What is frequency of scheduled maintenance?________________________
    ____
23. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ____
24. What is general condition of the trickling filter facilities? ( ) good ( ) fair ( ) poor
25. What are the most common problems the operator has had with the trickling filter system? ______________________________________
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

7. Benjes, H.H., Jr., Attached Growth Biological Wastewater Treatment Estimating Performance and Construction Costs and Operating and Maintenance Requirements, EPA Contract 68-03-2186 (January, 1977).

8. Battelle Pacific Northwest Laboratories, Evaluation of Municipal Sewage Treatment Alternatives, Council on Environmental Quality, Contract EQC316 (February, 1974).

8. ACTIVATED BIOFILTER PROCESS

Process Description

The activated biofilter (ABF) is the proprietary name for a treatment process combining a trickling filter with an activated sludge system. After primary sedimentation, wastewater flows to the filter (bio-cell) lift station where it is mixed with filter underflow and return activated sludge from the secondary sedimentation basins. This mixed liquor is distributed over the redwood slat trickling filter media and the organic matter in the waste is oxidized by the attached microbes growing on the media as well as the suspended microorganisms present in the return sludge. As the wastewater trickles through the media, it is naturally aerated. The underflow from the filter is split, with the majority going to the aeration basin and the remainder being recycled. The activated sludge system is generally equipped with mechanical surface aerators. This additional aeration provides supplemental BOD removal while producing a well-settling sludge. Final sedimentation is basically the same as that following standard activated sludge, except solids are recycled to the bio-cell rather than the aeration basin.

Typical Design Considerations

Although the design of an ABF system is not as simple as merely adding a trickling filter to an activated sludge system or vice-versa, the basic design theories of the individual systems are applicable. Generally, the trickling filter is designed to remove about 65 percent of the influent (primary effluent) BOD and the aeration basin is designed to remove the remainder. Table 8-1 presents the basic design criteria.

Typical Performance Evaluation

The performance of ABF systems has been evaluated in both pilot and full-scale applications. Overall, an ABF system can be expected to produce secondary effluent quality (20 to 30 mg/l BOD and SS) from domestic wastewater. By reducing the design loadings, it can produce roughly the same quality effluent from municipal wastewater with a significant industrial (particularly food processing) waste contribution.

TABLE 8-1. TYPICAL ACTIVATED BIOFILTER DESIGN CRITERIA

	Units	Typical Value	Range
EFFLUENT CRITERIA			
BOD_5	mg/l	20	10-30
Suspended solids	mg/l	20	10-30
BIO-CELL PARAMETERS			
Organic load	lb BOD/1000 cu ft/day	200	100-350
Media depth	ft	14	5-22
BOD removal	%	65	55-85
HYDRAULIC PARAMETERS			
Bio-cell recycle	*	0.4Q	0-2.0Q
Sludge recycle	*	0.5Q	0.3-1.0Q
Bio-cell flow	*	1.9Q	1.5-4.0Q
Bio-cell hydraulic load	gpm/sq ft	3.5	1.5-5.5
AERATION PARAMETERS**			
Detention time*	hrs	0.8	0.5-2.0
Organic load	lb BOD/1000 cu ft/day	95	50-225
F/M	lb BOD/MLVSS/day	0.5	0.2-0.9
MLVSS	mg/l	3000	1500-4000
MLSS	mg/l	4000	2000-5000
SLUDGE PRODUCTION	lb VS/lb BOD_5 removed	0.65	0.55-0.75

*Based on design average flow and secondary influent BOD=150 mg/l

**Based on aeration BOD_5 loading after bio-cell removal

The following example demonstrates the steps to be taken to evaluate ABF performance.

1. Determine operating conditions

   Flow
   - Influent to bio-cell = 3 mgd
   - Bio-cell recycle = 1.5 mgd
   - Sludge recycle = 1.5 mgd
   - Total to bio-cell = 6 mgd

   Bio-cell characteristics
   - Media depth = 14 ft
   - Surface area = 2,000 sq ft
   - Media volume = 28,000 cu ft

   Aeration basin characteristics
   - Volume = 17,000 cu ft
   - Hydraulic detention = 1 hr

   BOD
   - Influent to bio-cell = 150 mg/l
   - Influent to aeration basin = 72 mg/l
   - Effluent from final clarifier = 30 mg/l

2. Determine hydraulic loading rate on the bio-cell

   $$\text{Hydraulic Loading} = \frac{\text{Total flow in gpd}}{\text{Surface area in ft}^2}$$

   $$= \frac{6 \text{ mgd} \times 694}{2000 \text{ sq ft}} \text{ gpm/mgd} = 2.08 \text{ gpm/sq ft}$$

   This value is within the range presented in Table 8-1.

3. Determine organic loading rate on the bio-cell.

   $$\text{Organic Loading} = \frac{(\text{Flow, mgd}) \times (\text{BOD, mg/l}) \times (8.34 \text{ lb/gal})}{(\text{Vol, cu ft}) - 1000}$$

   $$= \frac{3.0 \times 150 \times 8.34 \times 1000}{28{,}000} = 134 \text{ lb BOD/1000 cu ft/day}$$

   This, too, is within the prescribed loading rate given in typical design criteria.

4. Determine minimum efficiency of bio-cell.

   $$\% \text{ BOD removal} = \frac{\text{BOD in} - \text{BOD out}}{\text{BOD in}} \times 100$$

   $$= \frac{150 - 72}{150} \times 100 = 52\%$$

   This should be considered an absolute minimum removal efficiency from the bio-cell; generally the removal is around 65 percent.

5. Determine the organic loading on the aeration basin.

$$\text{Organic loading} = \frac{(\text{Flow, mgd}) \times (\text{BOD, mg/l}) \times 8.34 \text{ lb/gal}}{(\text{Vol, cu ft}) \div 1000}$$

$$= \frac{3.0 \times 72 \times 8.34 \times 1000}{17000} = 106 \text{ lb/BOD } 1000 \text{ cu ft/day}$$

This value is again within the acceptable range for organic loadings on the aeration basin.

6. Determine the removal efficiency in the aeration basin. The value calculated will be a maximum for this example since that for the bio-cell was a minimum.

$$\% \text{ BOD removed} = \frac{72 - 30}{72} \times 100 = 58\%$$

7. Determine the overall process efficiency.

$$\% \text{ BOD removal} = \text{Bio-cell removal} + \text{aeration basin removal} - (\text{Bio-cell removal} \times \text{aeration basin removal})$$

$$= 0.52 + 0.58 - (0.52 \times 0.58) = 0.80 \text{ (or } 80\%)$$

Overall BOD removal efficiency can also be determined as follows:

$$\% \text{ BOD removal} = \frac{BOD_{in} - BOD_{out}}{BOD_{in}} \times 100$$

$$= \frac{150 - 30}{150} \times 100 = 80\%$$

8. Determine recirculation rates

$$\text{Bio-cell recirculation} = \frac{\text{Bio-cell recycle}}{\text{Influent to bio-cell}}$$

$$= \frac{1.5 \text{ mgd}}{3.0 \text{ mgd}} = 0.5$$

$$\text{Sludge recirculation} = \frac{\text{sludge recycle}}{\text{Influent to bio-cell}}$$

$$= \frac{1.5 \text{ mgd}}{3.0 \text{ mgd}} = 0.5$$

Both of these values are typical for the ABF process. They can be varied over fairly wide ranges as indicated in Table 8-1 to provide a good deal of process flexibility and control.

Process Control

The control of the ABF process is much like the control of the activated sludge process, with the bio-cell serving as a mixed liquor aerator. The activated sludge control considerations in Section 6 of this manual should be reviewed for information relevant to the ABF process. Detailed trickling filter control considerations in Section 7 are generally applicable to ABF bio-cells.

Return sludge rates of 50 percent of the average flow rate and bio-cell recycle rates of 50 percent of the average flow rate are most often used.

Maintenance Considerations

Use maintenance information for Sections 6 and 7, activated sludge and trickling filters.

Records

Recommended sampling and laboratory tests are shown in Figure 8-1.

Other operating records should include:

1. Raw sewage influent flow.
2. Recirculation flow.
3. Return and waste activated sludge flows.
4. MLSS and MLVSS in the aeration basin and the return sludge line.
5. The unit volume of air supplied per lb of BOD removed in the aeration step.
6. Frequency and duration of operation of the RAS and WAS pumps.
7. The total energy (electricity) consumed.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the activated sludge process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be referred to for any detailed questions.

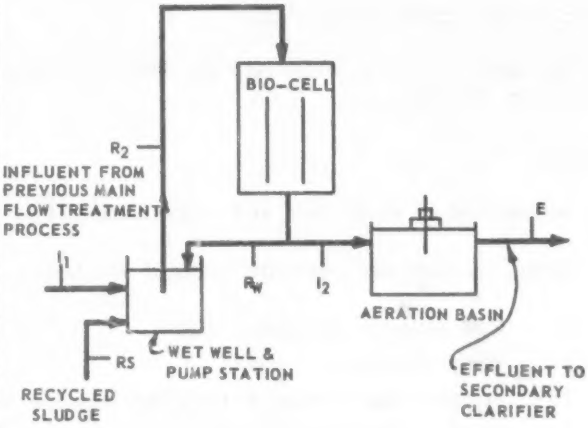
Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as at the bio-cell recirculation lift station or in the

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

ACTIVATED BIOFILTER PROCESS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I_1 I_2	24C	P
	SUSPENDED SOLIDS	ALL	5/W	E_2	24C	P
	SETTLEABILITY	ALL	5/W	E_2	G	P
	pH	ALL	5/W	I_2 E	G	P
	DO	ALL	5/W	I_2 E	G	P
	FLOW	ALL	R	I, R_1, R_2, RS	R	P
OPTIONAL	COD	>5	2/W	I_1 E	24C	H
	TOTAL SOLIDS	>1	3/W	E	24C	H
	TOTAL VOLATILE SOLIDS	>1	3/W	E	24C	H
	MICROSCOPIC ANALYSES	ALL	2/W	R_1 E	G	H


BIO-CELL
R2
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
E
I1
RW
I2
AERATION BASIN
RS
WET WELL & PUMP STATION
RECYCLED SLUDGE
EFFLUENT TO SECONDARY CLARIFIER

A. **TEST FREQUENCY**

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. **LOCATION OF SAMPLE**

I_1 = INFLUENT TO WETWELL
I_2 = INFLUENT TO AERATION BASIN
E = EFFLUENT FROM AERATION BASIN
RS = RECYCLED SLUDGE
R_1 = BIO-CELL RECYCLE
R_2 = BIO-CELL RECIRCULATION

C. **METHOD OF SAMPLE**

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. **REASON FOR TEST**

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. **FOOTNOTES:**

1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 8-1

aeration basin close to the mixing device or from the sludge lines after the sludge has been flowing for about a minute. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the bio-cell underflow or aeration basin effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The sidestreams from the ABF process are similar to those from activated sludge and are discussed in the section regarding secondary sedimentation. In general, the recycling of sludge to the bio-cell and the accumulation of solids (humus) in that unit reduces the total solids production from the process.

Process Checklist - ABF

1. What is actual plant flow?________ mgd, average; ________mgd, peak
2. What is underflow recycle rate __________mgd? What is the solids recycle rate to the bio-cell __________mgd?
3. What type of media is used in the bio-cell?__________________
4. What is the depth of media ____________ feet?
5. Number of bio-cell units ___________; Size of bio-cell units __________
6. Type of aeration system (flow regime) ____________________
7. Type of aeration equipment __________________; Number of units ________
   Capacity of each unit _______________; Tank dimensions __________
8. Color of bio-cell growth:
   ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
   Color of activated sludge:
   ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other______________
9. Odor of bio-cell growth:
   ( ) Septic ( ) Earthy ( ) None ( ) Other ________________
   Odor of activated sludge:
   ( ) Septic ( ) Earthy ( ) None ( ) Other ________________
10. Is there evidence of uneven flow distribution? ( ) Yes ( ) No. Are any nozzles clogged? ( ) Yes ( ) No
11. Is there evidence of bio-cell clogging, such as ponding? ( ) Yes ( ) No.
12. Is there evidence of filter flies? ( ) Yes ( ) No. Snails? ( ) Yes ( ) No. Roaches? ( ) Yes ( ) No. Other ________________
13. Is there grass or other vegetative material growing on bio-cell? ( ) Yes ( ) No. Other ______________________
14. Are there flow measurement devices for the recirculation and return sludge flows? ( ) Yes ( ) No. Are they operable? ( ) Yes ( ) No
15. Are recirculation lift station and RAS pumps operating? ( ) Yes ( ) No. If no, what is the reason? ______________________________
16. If multiple bio-cells are operating, is the flow distributed equally? ( ) Yes ( ) No. How is it distributed?______________________
17. Are the characteristics of the bio-cell contents in each bio-cell different? ( ) Yes ( ) No. If yes, describe ____________________
    ____
18. Are aeration tank contents mixed thoroughly? ( ) Yes ( ) No
19. Are mechanical aerators operating properly? ( ) Yes ( )No
20. Does mixing appear excessive? ( ) Yes ( ) No
21. Do there appear to be dead spots in the aeration tank? ( ) Yes ( ) No If yes, at what location? ______________________________
22. Is the process operating in its design mode? ( ) Yes ( ) No. If no, explain ____________________________________
23. Does the aeration basin have a foam control system?( ) Yes ( ) No. Is it operable? ( ) Yes ( ) No
24. Is the aeration tank area provided with adequate safety features (guardrails, nonskid surfaces, life preservers, lights)? ( ) Yes ( ) No
25. If multiple basins for each step are operating, is the flow distributed equally? ( ) Yes ( ) No. How is it distributed?________________
26. Is operation of the system ( ) Manual ( ) Semi-Automatic ( ) Automatic ( ) Computer controlled ( ) Other ______________

27. Does mechanical equipment (flow distributors, pumps, mechanical aerators, etc) have adequate spare parts inventory? ( ) Yes ( ) No

28. Is the pump station housing adequately ventilated? ( ) Yes ( ) No

29. How often are facilities checked? ( ) once per shift ( ) daily
( ) Other ____________________

30. What is frequency of scheduled maintenance? ______________________________
____

31. Is the maintenance program adequate? ( ) Yes ( ) No
If no, explain ____

32. What is general condition of the ABF facilities?
( ) good ( ) fair ( ) poor

33. What are the most common problems the operator has had with the ABF system?
____
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

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9. Dunnahoe, R.G., and Hemphill, B.W., The ABF Process, A Combined Fixed/Suspended Growth Biological Treatment System, AWWA-FACE Conference (September 1976).

9. LAGOONS

Process Description

Lagoons, or stabilization ponds are commonly used in the U.S. to treat domestic wastewater from small communities (less than 10,000 people) and have some application in treating industrial wastes. Lagoons are generally simple basins enclosed by earthen dikes.

Lagoons can be classified by many characteristics including depth, rate of waste loading, detention time, source of oxygen or type of biological activity. There are four principal types - aerobic, anaerobic, facultative, and aerated. Since anaerobic lagoons are rarely used for municipal wastewater treatment, this discussion will be limited to the other three lagoon systems.

A simple aerobic lagoon or oxidation pond is a shallow pond in which organic materials are degraded by aerobic bacteria. The dissolved oxygen (DO) is supplied by oxygen transfer between the air and water surface and by algae growth. The amount of oxygen supplied by natural surface aeration is not dependable, therefore the oxygen supplied by algae photosynthesis is considered limiting in design.

Facultative lagoons provide a more complex environment in which waste stabilization occurs. The surface of a facultative lagoon is similar to that of an aerobic lagoon in that bacteria and algae provide organic stabilization. Solids settle to the lower depths of the lagoon and are anaerobically decomposed. In the intermediate zone, facultative bacteria, oxidize the dissolved solids in the influent wastewater. Mechanical aeration equipment is sometimes provided for mixing the upper zone of a facultative lagoon and to augment natural aeration.

Aerated lagoons do not depend on algae and sunlight supplying the necessary DO for bacteria but diffusers or mechanical aerators are used to supply oxygen and suspend the solids by mixing action in the wastewater. A separate sedimentation step is required. Aerated lagoons are commonly arranged in series for improved BOD removal and can be followed by an aerobic lagoon acting as a polishing pond or sedimentation step for suspended solids removal.

Typical Design Considerations

Properly designed and operated lagoon systems are capable of producing high removals of organic materials, solids, and bacteria. Design criteria for the three lagoon types described in this chapter are given in Table 9-1.

Typical Performance Evaluation

In evaluating the performance of a lagoon, the evaluator should check the system records to see that effluent BOD_5 and SS concentrations are generally within the expected ranges presented in Table 9-1. The following step-by-step procedure shows how to evaluate lagoons:

TABLE 9-1. EMPIRICAL DESIGN CRITERIA FOR WASTE STABILIZATION LAGOONS

Parameter	Aerobic	Facultative	Aerated	
			Aerobic	Facultative
Flow regime			Completely mixed	Mixed surf. layer
Lagoon size (acres multiples)	10 acre multiples	2-10 multiples	2-10 multiples	2-10 multiples
Operation	Series or parallel	Series or parallel	Series or parallel	Series or parallel
Hydraulic retention time (days)	10-40	7-30	3-20	7-20
Depth (ft)	3-4	3-6	6-20	3-8
Hydraulic loading (in./day)	3-5	0.5-1.5	- -	- -
BOD_5 loading:				
(lb/day/acre)	60-120	15-50	20-400	- -
(lb BOD/day/1,000 cu ft)	- -	- -	- -	- -
Optimum temperature (°C)	20	20	20	20
Temperature range (°C)	0-40	0-50	0-40	0-50
BOD_5 removal efficiency (%)	80-95	80-95	80-95	80-95
Algal concentration (mg/l)	80-200	40-160	- -	- -
Coliform removal %	>99	>99	- -	- -
Algae	$(0.4\text{-}1.2)(BOD_5)_i$	$(0.2\text{-}0.8)(BOD_5)_i$	$(0.02\text{-}0.1)(BOD_5)_i$	$(0.02\text{-}0.1)(BOD_5)_i$
Microorganisms	$(0.2\text{-}0.5)(BOD_5)_i$	$(0.2\text{-}0.5)(BOD_5)_i$	$(0.2\text{-}0.5)(BOD_5)_i$	$(0.2\text{-}0.5)(BOD_5)_i$
Other	Low	$(0.1\text{-}0.4)(SS)_i$	$(1.1\text{-}1.4)(SS)_i$	$(0.1\text{-}0.4)(SS)_i$
Effluent BOD_5 (mg/l):				
Soluble BOD_5	$(0.02\text{-}0.1)(BOD_5)_i$	$(0.02\text{-}0.1)(BOD_5)_i$	$(0.02\text{-}0.1)(BOD_5)_i$	$(0.02\text{-}0.1)(BOD_5)_i$
Insoluble BOD_5	$(0.3\text{-}1.2)(SS)_e$	$(0.3\text{-}1.0)(SS)_e$	$(0.5\text{-}0.8)(SS)_e$	$(0.3\text{-}0.8)(SS)_e$
Typical effluent quality, (mg/l):				
BOD_5	15-40	15-40	20-70	20-70
SS	25-50	25-50	- -	- -
pH	6.5-10.5	6.5-9.0	6.5-8.5	6.5-8.5
Oxygen source	Algae	Algae	Aerators	Aerators
Aerator design goals	- -	- -	Aeration plus mixing	Aeration

i = influent, e = effluent

1. Determine the design criteria for the pond system.

Type of Pond - Facultative
Pond Dimensions
Area, A = 872,356 ft^2 or 20 acres
Depth, D = 3 ft
Volume, V = A x D = 60 acre-ft
Flow = 1.0 mgd
Influent BOD = 300 mg/l

2. Determine the detention time of the wastewater within the pond.

$$\text{Detention Time} = \frac{(\text{V in acre-ft})\ (7.48\ \text{gal/ft}^3)\ (43{,}560\ \text{ft}^2/\text{ac})}{(\text{Flow in gpd})}$$

$$= \frac{(60)\ (7.48)\ (43{,}560)}{(1 \times 10^6)}$$

$$= 20\ \text{days}$$

For a facultative lagoon, Table 9-1 shows that a 20-day detention time is within the acceptable 7- to 30-day range.

3. Determine the organic loading for the pond.

$$\text{Organic Loading} = \frac{(\text{Flow in mgd})\ (\text{BOD, mg/l})\ (8.34\ \text{lb/gal})}{(\text{Area in Acres})}$$

$$= \frac{(1)\ (300)\ (8.34)}{(20)}$$

$$= 125\ \text{lbs BOD/day/acre}$$

By checking Table 9-1 the organic loading of the lagoon is higher than normally expected. If the pond is not performing as desired, the referenced design shortcomings and troubleshooting guide should be consulted for possible solutions to remedy this problem.

To achieve best results, lagoons must be operated to provide enough mixing to distribute the influent and settleable solids throughout the pond. In unaerated ponds, mixing is provided by wind and wave turbulence, as well as at inlets and outlets.

For the light to moderately loaded lagoon, sludge usually does not accumulate in large quantities, although there may be small deposits near the inlet and in cold weather over wider areas. For moderate to heavily loaded lagoons, sludge accumulation may be more significant and it may need to be removed and disposed of. The accumulation of sludge must be carefully controlled since the performance of the pond will be reduced, as measured by the SS content of the effluent.

There are four operation strategies presented in Table 9-2. Aerated lagoon process control strategy consists mainly in aeration control. Aerators are usually constant speed so variation is accomplished by time-clock-controlled operation. By this procedure those aerators that are unnecessary during warm summer afternoons (high algae concentration) can be turned off. During early morning hours or during peak conditions more aerators can be turned on.

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are listed below. General features for both unaerated and aerated ponds are followed by those relating specifically to systems with mechanical equipment. These should be used in conjunction with general maintenance management guidelines.

1. Scheduled inspection of the pond linings and/or levees.
2. Weed control program.
3. Insect control in the vicinity of the lagoons.
4. Burrowing animals control.
5. Regular inspection of the lagoon site for visible signs of process upset or vandalism of the facilities. Mechanical equipment, such as automatic effluent level controls, should also be routinely checked and tested to insure proper operation.
6. Regular inspection of aerated lagoons and oxygen transfer facilities (i.e., mechanical aerators,) to visibly inspect the equipment for abnormalities.
7. Spare part inventory should contain at least the following parts: one set of each type of bearing, grease seals, all necessary gasket for replacement of parts, one set each of mechanical seals, washers or sheaves to allow for adjustment of impellers.
8. Daily readings of mechanical aerators operating times. These can be used for plant operations and also for scheduling regular maintenance work.
9. Periodic tests run on each aerator to ensure that it operates at the same conditions as when it was supplied.
10. All non-operating equipment, such as basin dewatering pumps, sluice gates and weir gates or standby electric generators, should be tested at least once per month.

TABLE 9-2. ALTERNATIVE OPERATIONAL STRATEGIES FOR UNAERATED AEROBIC AND FACULTATIVE LAGOONS

	Operational Strategy							
	Continuous Discharge				Semicontinuous Discharge			
Parameter	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Discharge:								
Continuous	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Short period only	No	No	No	No	No	Yes	No	No
Operating level:								
Constant	Minimum	-	-	Decrease	-	-	Optimum	-
Gradual change	-	Increase	Maximum	-	Increase	-	-	Decrease
Short period change	-	-	-	-	-	Decrease	-	-
Multicell flow pattern:								
Parallel	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Series	No	No	Yes	No	No	No	Yes	No
Climate	Warm				Cold			

	Operational Strategy							
	Intermittent Discharge				No Discharge			
Parameter	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Discharge:								
Continuous	No	No	No	No	No	-	-	-
Short period only	No	Yes	No	Yes	No	-	-	-
Operating level:								
Constant	-	-	-	-	-	-	-	-
Gradual change	Increase	-	Increase	-	Increase	Varies	Decrease	Varies
Short period change	-	Decrease	-	Decrease	-	-	-	-
Multicell flow pattern:								
Parallel	No	No	No	No	Not applicable			
Series	Yes	Yes	Yes	Yes				
Climate	Harsh				Arid			

Records

Recommended sampling and laboratory tests for aerated and unaerated lagoons are shown in Figures 9-1 and 9-2.

Other operating records should include:

1. Raw sewage influent flow.
2. Return and waste activated sludge flows (for aerated systems with solids recycle).
3. MLSS and MLVSS in the aeration basin and the return sludge line (for aerated systems with solids recycle).
4. The unit volume of air supplied per lb of BOD removed (for aerated systems).
5. Frequency and duration of operation of the RAS and WAS pumps (for aerated systems with solids recycle).
6. The total energy (electricity) consumed (for aerated systems).
7. Graphical plots of pH and DO to characterize diurnal and seasonal variations in lagoon operation.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the lagoon treatment process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment
6. pH meter

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be referred to for any detailed questions.

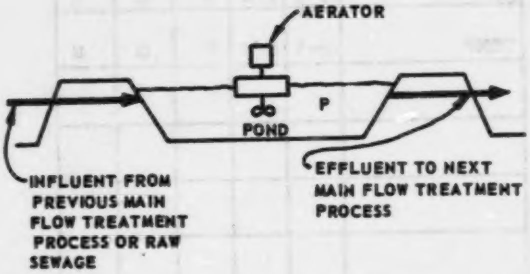
Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as in aerated lagoons close to the mixers. Samples obtained from naturally aerated systems should be from a location in the center of the pond. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

AERATED POND [1]


AERATOR
P
POND
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS OR RAW SEWAGE
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
pH	0-5	3/W	P	G	H
DO	0-5	1/D	P	G	H
TEMP	0-5	1/D	P	G	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

P = POND

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

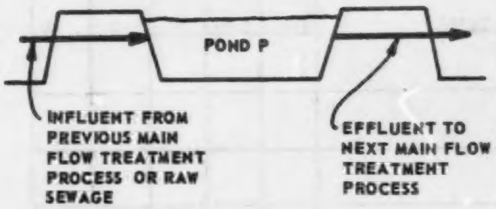
1. PROCESS NOT LIKELY FOR FLOWS GREATER THAN 5 MGD

Figure 9-1

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

STABILIZATION PONDS (1)
(OR POLISHING POND)


POND P
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS OR RAW SEWAGE
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	DO	0-5	1/W	P	G	H
	pH	0-5	1/W	P	G	H
	TEMP	0-5	1/W	P	G	H
OPTIONAL						

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

P = POND

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. PROCESS NOT LIKELY FOR FLOWS GREATER THAN 5 MGD

Figure 9-2

any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

Although many such ponds have functioned for years with little amounts of sludge build-up, there are exceptions to the rule. Any accumulated solids should be well digested and can be dewatered in sand beds and buried on site or at a sanitary landfill. This will only be required every few years.

Process Checklist - Aerated Lagoons

1. What is actual plant flow __________ mgd avg. __________ mgd peak?
2. Type of lagoon system ______________________________
3. Type of aeration system ______________ Number of units ______ and capacity of each unit ____________
4. What are the lagoon dimensions? ______________________________
5. Color ( ) Green ( ) Dark Brown ( ) Light Brown ( ) Other ______
6. Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ________
7. Foam ( ) light, crisp ( ) thick, dark ( ) heavy white ( ) Other ________
8. Are lagoon contents mixed thoroughly? ( ) Yes ( ) No (Aerobic lagoons should be, facultative lagoons should not)
9. Are all mechanical aerators operating properly? ( ) Yes ( )No
10. Does mixing appear excessive? ( ) Yes ( ) No
11. Do there appear to be dead spots in lagoon? ( ) Yes ( ) No If yes, at what location? ______________________________
12. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ______________________________
13. Does the lagoon basin have a foam or scum control system? ( ) Yes ( ) No Is it operable? ( ) Yes ( ) No. Is it operating? ( ) Yes ( ) No
14. If multiple lagoons are operating, is the flow distributed equally? ( ) Yes ( ) No How is it distributed? ______________ Are they operated in ( ) series, ( ) parallel?
15. Are the characteristics of the lagoon contents different in the various units ( ) Yes ( ) No. If yes, describe ______________ ______________________________
16. Is there vegetation growing in the lagoon or on the dikes? ( ) Yes ( ) No
17. Is there evidence of rodent burrowing on the dikes? ( ) Yes ( ) No
18. Is there an excessive insect population in the vicinity of the lagoon? ( ) Yes ( ) No
19. Does mechanical equipment (motors, mechanical aerators, etc.) have adequate spare parts inventory? ( ) Yes( ) No
20. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
21. How often are facilities checked? ( ) once per shift ( ) daily ( ) Other ____________
22. What is frequency of scheduled maintenance? ______________ ______________________________ ______________________________
24. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ______________________________
25. What is general condition of the lagoon facilities? ( ) good ( ) fair ( ) poor
26. What are the most common problems the operator has had with the lagoon system? ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Process Checklist - Unaerated Lagoons

1. What is actual plant flow __________ mgd avg. __________ mgd peak?
2. Type of lagoon system ______________________
3. What are the lagoon dimensions? ______________________________________
4. Color ( ) Green ( ) Light Brown ( ) Grey ( ) Other__________
5. Odor ( ) Septic ( ) Earthy ( ) None ( ) Other __________
6. Are lagoon contents properly mixed? ( ) Yes ( ) No
7. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ______________________________________
8. Does the lagoon basin have a foam or scum control system? ( ) Yes ( ) No Is it operable? ( ) Yes ( ) No. Is it operating? ( ) Yes ( ) No
9. If multiple lagoons are operating, is the flow distributed equally? ( ) Yes ( ) No. How is it distributed ______________________
10. Are the characteristics of the lagoon contents different in the various units ( ) Yes ( ) No, If yes, describe ______________________
    ____
11. Is there vegetation growing in the lagoon or on the dikes? ( ) Yes ( ) No
12. Is there evidence of rodents burrowing on the dikes? ( ) Yes ( ) No
13. Is there an excessive insect population in the vicinity of the lagoon? ( ) Yes ( ) No
14. How often are facilities checked?( ) once per shift ( ) daily ( ) Other ______________
15. What is frequency of scheduled maintenance?______________________
    ____
16. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ______________________________________
17. What is general condition of the lagoon facilities? ( ) good ( ) fair ( ) poor
18. What are the most common problems the operator has had with the lagoon system? ______________________________________
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

7. URS Research Company, Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants, EPA contract No. 68-01-0107.

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10. ROTATING BIOLOGICAL CONTACTORS

Process Description

Rotating biological contactors (RBC's) consist of large discs mounted on horizontal shafts in concrete tanks. Organisms attach and grow on the surface of the media forming a 1- to 4-mm thick layer of biomass for organic removal. The rotation of the reactor provides a source of oxygen for microbial growth and promotes mixing, keeping the wastewater solids in suspension. Shearing forces on the biomass as it passes through the liquid cause the excess growth to be stripped from the media surface. Sedimentation basins downstream of the RBC's are used to remove the excess growth from the waste stream. There is neither solids recycle nor liquid recirculation with RBC's.

Shafts of discs are arranged in stages. The first stages are provided with media having a specific unit surface area of 30 to 35 sq ft/cu ft, while the latter stages have a higher value - 45 to 50 sq ft/cu ft. The media shafts are generally designed with covers or in enclosures to provide efficient operation in low-temperature climates and to protect the biological surfaces against direct sunlight and rainfall which could affect growth.

Typical Design Considerations

The design of RBC treatment systems has been based on a graphical approach relating hydraulic loading to BOD removal. Figure 10-1 presents one manufacturer's design approach.

An alternative method of sizing RBC systems(9) is to use the equation

$$\frac{Le}{Lo} = e^{-S(As/Q)^{1/2}}$$

Where:

Le = BOD_5 out
Lo = BOD_5 in
S = A treatability factor related to surface area. A design value at 20° of 0.055 is appropriate.
As = Media surface area (sq ft)
Q = Hydraulic loading (gpm)

Temperature has little effect on RBC systems above 13^oC. Below 13^oC larger surface areas are required for the same treatment efficiency.

Typical Performance Evaluation

The process (including secondary sedimentation) should remove 75 to 80 percent of the influent BOD. When combined with primary treatment, BOD removals of 90 to 95 percent can be expected.

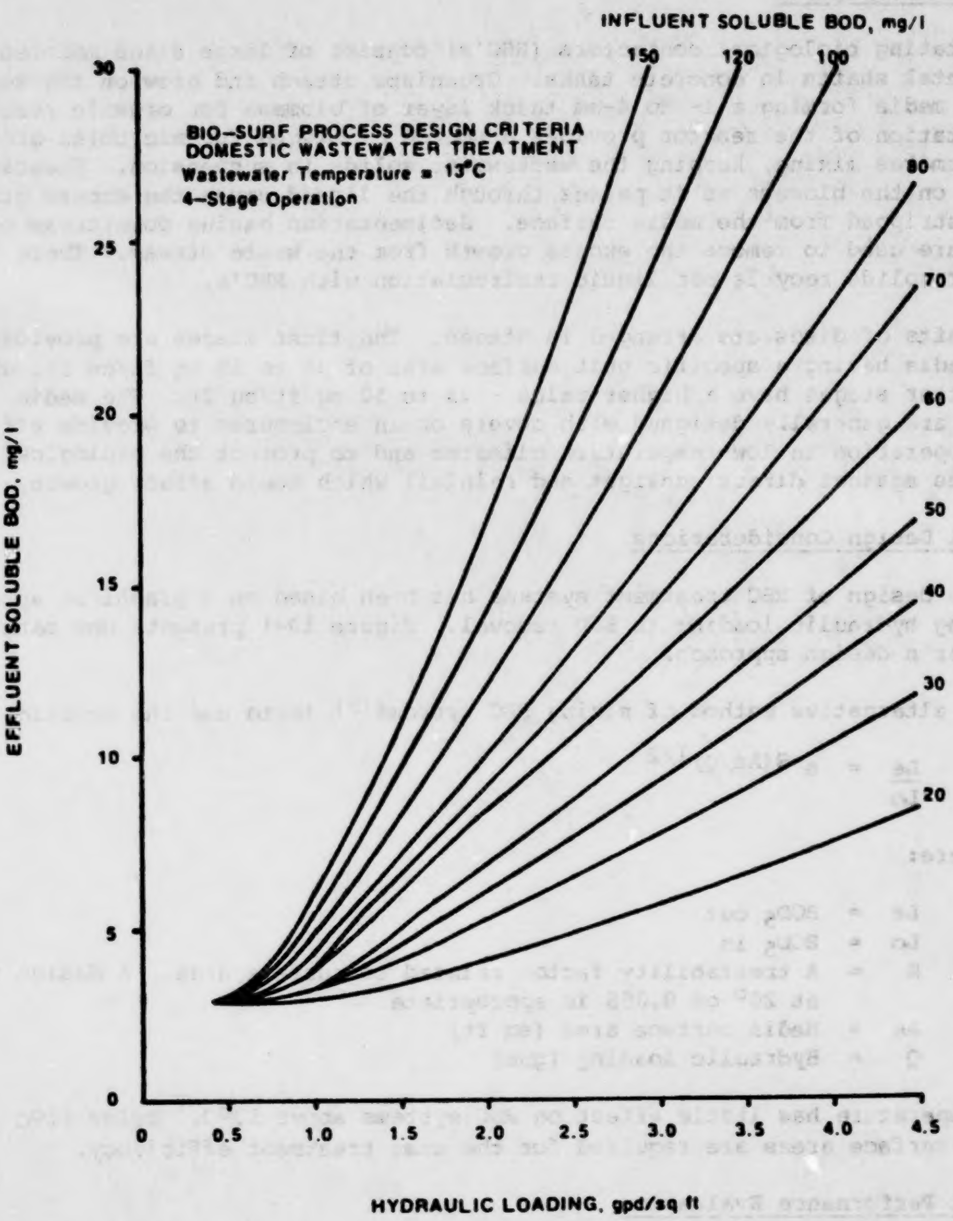


Figure 10-1. Rotating biological media for secondary treatment.

The following example is an evaluation of the performance of an RBC system.

1. Define the design and operating data for the system 4-stage system; 24 shafts, 100,000 sq ft of effective surface area on each shaft.

   Effective surface area
   Each stage = 600,000 sq ft
   Total = 2,400,000 sq ft
   Flow = 3.5 mgd
   BOD
   Influent, total = 150 mg/l
   , soluble (assume 65% of total) = 98 mg/l
   Effluent, total = 30 mg/l
   , soluble (assume 50% of total) = 15 mg/l
   Temperature = 20°C

2. Determine the hydraulic loading for the RBC system

   $$\text{Hydraulic Loading} = \frac{\text{Total flow in gpd}}{\text{Total surface area}}$$

   $$= \frac{3{,}500{,}000}{2{,}400{,}000}$$

   $$= 1.46 \text{ gpd/sq ft}$$

3. Determine the efficiency of the RBC system

   $$\% \text{ BOD removal} = \frac{BOD_{in} - BOD_{out} \times 100}{BOD_{in}}$$

   $$= \frac{150 - 30}{150} \times 100$$

   $$= 80\%$$

Process Control

The only operating variable with RBC's is the speed at which the shafts rotate. Generally, the units are equipped with mechanical drives to rotate the media at 1 to 3 rpm. This can be adjusted to compensate for changes in the wastewater characteristics and flow. Other areas that should be reviewed are sludge pumping and flow distribution. Sludge pumping schedules should be set so that septic sludge is avoided but dilute sludge is not pumping. Inadequate pumping results in septic sludge. Excessive pumping results in a thin sludge which causes inefficient dewatering performance and increases pumping costs. Poor flow distribution between units can cause overloading on one and a decrease in treatment efficiency.

Maintenance Considerations

The features of a good maintenance program are listed below. They should be used in addition to the general maintenance management program presented earlier.

1. Spare part inventory should contain at least the following parts: one set of each type of bearing, V-belt or chain drives for each system, and grease seals.
2. Inspection each shift of the discs and appurtenant facilities to visibly inspect the equipment for misalignment, constant rotative speeds, any excessive vibrations.
3. Record flow rate per kilowatt hour is determined for the mechanical drives. A deviation from an average value is a good indication of efficiency and changing conditions that might require maintenance.
4. All non-operating equipment, such as standby electric generators, is tested at least once per month.
5. Immersed instrumentation checked and cleaned weekly.

Records

Recommended sampling and laboratory tests are shown in Figure 10-2.

Other operating records should include:

1. Raw sewage influent flow.
2. The total energy (electricity) consumed.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the RBC process.

1. Analytical balance
2. Clinical centriguge with graduated tubes
3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be referred to for any detailed questions.

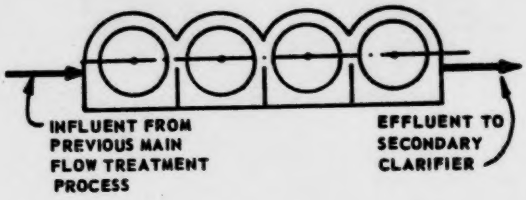
Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as in the influent and effluent lines. The sample collector and containers should be clean. A wide mouth sample collector of at

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

ROTATING BIOLOGICAL CONTACTOR


INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
EFFLUENT TO SECONDARY CLARIFIER

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	H
	DO	ALL	5/W	I E	G	H
OPTIONAL	COD	75	2/W	I	24C	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 10-2

least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

There are no sidestreams associated with the RBC process.

Process Checklist - Rotating Biological Contactors

1. What is actual plant flow __________ mgd avg. __________ mgd peak?
2. Type of RBC media ______________________________
3. Type of RBC drive ______________ Number of units (shafts) ________
   and surface area of each unit ______________
4. Color of biomass ( ) Black ( ) Dark Brown ( ) Light Brown
   ( ) Other ______________
5. Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ______________
6. Are all mechanical drives and motors operating properly? ( ) Yes ( ) No
7. Is rotation of media uniform? ( ) Yes ( ) No
8. Is the flow distributed equally to parallel shafts? ( ) Yes ( ) No
   How is it distributed? ______________________________
9. Are the characteristics of the tank contents different in the various units? ( ) Yes ( ) No. If yes, describe ______________
   ____
10. Do mechanical equipment (mechanical drives, motors, etc.) have adequate spare parts inventory? ( ) Yes ( ) No
11. Is the RBC housing adequately ventilated? ( ) Yes ( ) No
    Is RBC housed in a building? ( ) Yes ( ) No, or is each unit equipped with a cover? ( ) Yes ( ) No
12. How often are facilities checked? ( ) once per shift ( ) daily
    ( ) other ______________
13. What is frequency of scheduled maintenance? ______________
    ____
14. Is the maintenance program adequate? ( ) Yes ( ) No
    If no, explain ______________________________
15. What is general condition of the RBC facilities? ( ) good ( ) fair
    ( ) poor
16. What are the most common problems the operator has had with the RBC system? ______________________________
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).
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11. SECONDARY SEDIMENTATION

Process Description

Secondary sedimentation basins are very similar in structure to primary sedimentation basins, but are used to remove biological solids from the waste stream. In the case of activated sludge systems they also provide a source of concentrated return sludge for return to the aeration basin. Secondary sedimentation basins can be circular, square, or rectangular. They are equipped with scrapers or suction type sludge removal units. The scrapers are generally used for light sludges in smaller diameter tanks (less than 50 feet) while the suction mechanisms are installed in larger tanks. Surface skimming is also necessary to prevent the escape of floating materials in the effluent. A radial scum arm with a blade moves the scum to the periphery of the clarifier and deposits it in a disposal trough.

Typical Design Considerations

The design of the secondary sedimentation basins is critical to the overall performance of a treatment facility and is dependent upon the upstream biological process. Table 11-1 summarizes loading rates for these basins.

Sedimentation basins are ordinarily sized using a surface overflow rate as described previously in Section 5. The example given in Section 5 applies equally to secondary sedimentation basins as to primary sedimentation basins, however, the loading rates are different. Providing adequate surface area for peak flows is also critical since the overall plant performance is directly related to the sedimentation basin performance.

In the case of sedimentation following activated sludge, additional design criteria must be considered. Because large solids concentrations limit settling rates, the surface area requirement may be governed by the solids loading rate; this is particularly true when the mixed liquor suspended solids (MLSS) is greater than 2,000 to 3,000 mg/l. The criteria providing the largest surface area should be used to insure adequate liquid-solids separation at all times.

Typical Performance Evaluation

The performance of secondary wastewater treatment systems is determined by comparing the quality of the overflow from the secondary clarifiers to that of the incoming wastewater. Typical removals for secondary treatment facilities are given in the previous sections dealing with biological treatment processes.

Process Control

There are different operational considerations depending on the nature of the upstream processes. Sedimentation following trickling filters or other attached growth processes is similar to primary sedimentation in that there is no solids recycle. Trickling filter humus typically has a solids concentration of 5 to 10 percent and can be pumped as described for primary sludge.

TABLE 11-1. TYPICAL LOADING RATES FOR SECONDARY SEDIMENTATION BASINS

Type of treatment	Overflow rate Average	 Peak	Solids loading Average	 Peak	Depth
	gpd/sq ft		lb solids/day/sq ft		ft
Settling following trickling filtration	400-600	1,000-1,200	- -	- -	10-12
Settling following activated sludge	400-800	1,000-1,200	20-30	< 50	12-15
Settling following oxygen-activated sludge with primary settling	400-800	1,000-1,200	25-35	<50	12-15

Allowable solids loadings are governed by sludge settling characteristics.

On the other hand, the controls of secondary sedimentation systems are part of the activated sludge process. The secondary sedimentation basins should not be used as a storage basin for activated sludge; the sludge should be removed and a portion of it returned to the aeration tanks as quickly as possible. Best return rates are often in the range of 20 to 50 percent of the secondary inflow rate for most systems. The sludge level in each basin should not be greater than one-quarter the total basin depth. The sludge level is controlled by the sludge removal rate. Some of the removed solids are wasted from the system and the remainder returned to the aeration basins. Excessive sludge inventory in the secondary sedimentation basins can lead to loss of sludge over the basin effluent weirs, causing high effluent solids.

Scum should be properly removed from the secondary basins. Excessive skimming will result in too much water being carried over with the scum. If insufficient scum is removed, it will flow around or under the baffle and leave the tank in the effluent.

Equal flow distribution should be provided among all available secondary settling tanks. Even with equal distribution of flow, some differences in efficiencies may be found between two or more units. With unequal flow, however, less SS and BOD will be removed overall.

Maintenance Considerations

The features of a good maintenance program that the inspector should note include the items listed below. These should be used in addition to general maintenance management consideration presented earlier.

1. Scheduled inspection and maintenance of baffle boards and scraper.

2. Inspection of scum removal equipment.

3. Spare part inventory should contain the following: turntable gears and motors for circular basins, wear shoes, sprockets, wall brackets, chain pins and flights, shear pins, and cable for travelling bridges.

Records

Recommended sampling and laboratory tests are shown on Figure 11-1.

Other operating records are directly related to the biological treatment process preceding secondary sedimentation. The appropriate section of this report should be consulted for additional information.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor secondary sedimentation. In addition, the equipment required to monitor the biological process will be needed.

1. Analytical balance
2. Clinical centrifuge with graduated tubes.
3. BOD incubator
4. Drying oven
5. Imhoff Cones

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc. and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed such as at the center of the channel of flow where velocities are high. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

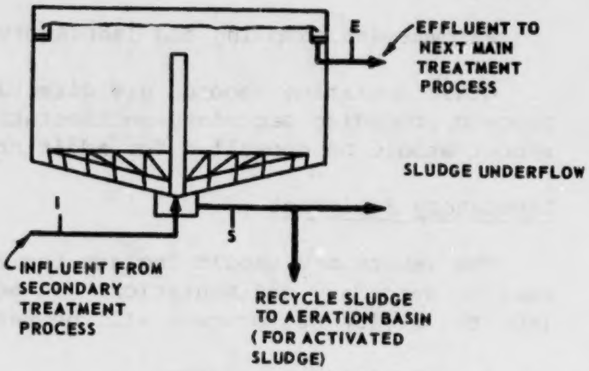
The only sidestream from secondary sedimentation is the sludge pumped from the basin. The solids from an activated sludge plant are either returned to the aeration tank (RAS) or wasted (WAS) to the primary sedimentation tank, thickeners, or digester. Generally, 85 to 95 percent of the settled sludge is returned to the process. The actual amount must be determined by the plant control considerations as discussed in Section 6. Trickling filter sludge is

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

SECONDARY CLARIFIER

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	SUSPENDED SOLIDS	ALL	3/W	I E	24C	P
	BOD	ALL	2/W	E	24C	H
	SETTLEABLE SOLIDS	ALL	1/D	I E	G	P
	TOTAL SOLIDS	<1	3/W	S	G	P
	NH_3-N[1]	ALL	1/D	E	24C	H
	ORG-N[1]	ALL	1/W	E	24C	H
	NO_3-N[1]	ALL	1/D	E	24C	H
	TOTAL-P[1]	ALL	1/D	E	24C	H
	ORTHO-P[1]	ALL	1/D	E	24C	H
	FLOW	ALL	R	WS RS	R	P
	SLUDGE VOLUME LAB CENTRIFUGE	>1	3/D	S	G	P
	TOTAL SOLIDS	>1	1/W	S	G	P
OPTIONAL	ALKALINITY	ALL	1/W	1	24C	P
	pH	ALL	1/D	1	G	H
	TURBIDITY	>15	Mn	E	Mn	P


E
EFFLUENT TO NEXT MAIN TREATMENT PROCESS
SLUDGE UNDERFLOW
I
S
INFLUENT FROM SECONDARY TREATMENT PROCESS
RECYCLE SLUDGE TO AERATION BASIN (FOR ACTIVATED SLUDGE)

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
S = SLUDGE UNDERFLOW
WS = WASTE SLUDGE
RS = RECYCLE SLUDGE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. TO BE RUN IF PROCESS IS DESIGNED TO CONTROL THIS PARAMETER

Figure 11-1

not recycled back to the process. Generally, it is pumped back to the head of the plant upstream of the primary sedimentation basins, to thickening tanks, or directly to digesters.

Regardless of the type of secondary sludge or where it is being pumped, pumping should be on a continuous basis. Standby units or adequate pumping flexibility should be provided to avoid interrupted or intermittent operation.

Process Checklist - Secondary Sedimentation

1. What is the total flow to the sedimentation basins _________ gpd average, _________ gpd peak.
2. What is the design flow _________ gpd average, _________ gpd peak? What are the dimensions of the sedimentation basin?_________________.
3. Is chemical addition used to improve settling? If so, what chemical(s) are added?__________________ ______________________, and for what reason?__________________________ What are the dose rate(s)____
4. How much sludge is pumped _________ gpd total, _________ gpd RAS, _________ gpd WAS?
5. What is the solids concentration in the sludge?_________________%
6. Are there settleable solids in the effluent _________________ mg/liter?
7. Is sludge pumping ____________ manual ____________ automatic ____________ continuous ________________ intermittent? ______________ other?
8. How often do sludge pumps run ________________ minutes/hour?
9. Frequency of maintenance inspections by plant personnel ___________/year.
10. Is maintenance program adequate? ( ) Yes ( ) No
11. Does the influent baffle system accomplish its purpose? ( ) Yes ( ) No
12. Is the scum collection system operating properly? ( ) Yes ( ) No
13. Is the sludge collection system operating properly? ( ) Yes ( ) No
14. Does the sludge collection system show any signs of mechanical failure? ( ) Yes ( ) No
15. Does the tank surface indicate improper sludge withdrawal? (i.e. excessive floating solids, gas...) ( ) Yes ( ) No
16. Is there an excessive accumulation of scum? ( ) Yes ( ) No
17. Does the effluent baffle system accomplish its purpose? ( ) Yes ( ) No
18. Are the effluent weirs level? ( ) Yes ( ) No
19. Are the effluent weirs kept clean? ( ) Yes ( ) No
20. If multiple units are used, is the flow distributed evenly? ( ) Yes ( ) No
21. Does the unit show signs of short circuiting and/or overloads? ( ) Yes ( ) No
22. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
23. Does the sampling program meet the recommendations? ( ) Yes ( ) No
24. Are operating records adequate? ( ) Yes ( ) No
25. Is the laboratory equipped for the necessary analyses? ( )Yes ( ) No
26. What spare parts are stocked? ____
____
____
27. What are the most common problems the operator had had with the process?
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

12. CHLORINATION

Process Description

The most common method of wastewater disinfection is by chlorination. Chlorine is added to the treated effluent to destroy any bacteria, pathogens or viruses. Other principal uses of chlorine are for odor control, and often times for control of bulking activated sludge. Chlorine application systems are described in Reference 1 and 2.

Typical Design Considerations

The design criteria and related performance of a chlorination system depends upon whether the chlorine is being applied strictly for disinfection purposes or, in the case of advanced waste treatment, for removal of nitrogen. Chlorine dosages vary for the two different applications.

The destruction of pathogens by chlorination is dependent upon water temperature, pH, time of contact, degree of mixing, turbidity, presence of interfering substances, and the concentration of chlorine available. Table 12-1 provides a general indication of chlorine dosage ranges for disinfecting wastewater after various degrees of pretreatment.

TABLE 12-1. ESTIMATE OF CHLORINE DEMAND FOR VARIOUS WASTEWATERS

Raw fresh domestic waste	8-15 ppm
Raw septic domestic waste	15-30 ppm
Primary sedimentation effluent	8-15 ppm
Recirculated biofilter effluent	5-8 ppm
Biofilter effluent (secondary)	3-8 ppm
Trickling filter effluent	3-10 ppm
Activated sludge effluent	2-8 ppm
Sand filtered effluent	1-5 ppm
Septic tank effluent	30-45 ppm

Breakpoint chlorination is also used in advanced wastewater treatment facilities for nitrogen removal. Chlorine is added to convert ammonia nitrogen to nitrogen gas. With the exception of the chlorine dosages, which may be anywhere from 40 to 50 times greater than that required for disinfection purposes only, the nitrogen removal process involves essentially the same equipment. Wastewater (after secondary or tertiary treatment) enters the chlorine contact chamber at which point chlorine is added and completely dispersed with incoming flow. In the breakpoint chlorination process about 10 mg/l of chlorine must be added for each 1 mg/l of ammonia nitrogen present in the wastewater. A more highly treated wastewater requires less chlorine to reach breakpoint. The breakpoint process can result in 99% plus percent removal of ammonia nitrogen, reducing concentrations to less than 0.1 mg/l (as N).

Typical Performance Evaluation

To determine the adequacy of the chlorination system to accomplish disinfection or other objectives the evaluator should examine the chlorine contact basin detention time, the chlorine residual in the basin effluent, and the MPN count of coliform organisms after chlorination. This evaluation can be performed very easily in the following steps:

1. Obtain design and typical operating data for the chlorination system being studied.
   Example:

Type of Effluent	Activated Sludge
Peak plant flow	5.0 mgd
Volume of chlorine contact tank, V	13,926 cu ft
Chlorine dosage	6.0 mg/l
Chlorine residual	1.0 mg/l

2. Determine the contact time for the chlorine contact tank based on peak flow.

$$\text{Contact time, hrs} = \frac{\text{V in cu ft} \times 7.48\ \text{gal/cu ft} \times 24\ \text{hrs/day}}{\text{Flow in gpd}}$$

$$= \frac{(13{,}926)\ (7.48)\ (24)}{5 \times 10^6}$$

$$= 0.50\ \text{hrs or 30 min}$$

3. Examine the daily disinfection log sheet for chlorine feed rates and chlorine residual patterns. Compare calculated contact time and measured chlorine residuals with the values for these parameters established by the proper regulatory agency. As a general rule, if the residual falls between 0.2 mg/l and 1.0 mg/l and there is 15 to 30 minutes of contact time there should be reasonable assurances of good disinfection. In the above example the 30 minutes of contact time with a 1.0 mg/l of chlorine residual effluent should indicate that the plant is meeting appropriate standards.

Process Control

In general the better the treatment plant is operated the easier it will be to disinfect the effluent. A poorly treated effluent will contain high levels of bacteria and higher concentrations of suspended solids which will increase the chlorine requirement. Effective disinfection of chlorine is dependent upon the combined effect of chlorine dosage, mixing and contact time with the wastewater. Overall process control is accomplished by measurement of the effluent chlorine residual. Maintenance of the proper chlorine residual is dependent upon the adequacy of the chlorination system to respond to changes in chlorine demand.

Applying chlorine to wastewater in a well mixed system produces a much higher degree of disinfection than when chlorine is fed without mixing, even though the contact time and residual are adequate. Longer contact times are more important than higher chlorine dosages or residuals in wastewater disinfection.

In breakpoint chlorination for nitrogen removal the system must be able to respond quickly to changes in ammonia nitrogen concentration, chlorine demand, pH, alkalinity and flow. Failure to closely match chlorine dosage to ammonia concentration can result in incomplete nitrogen removal or chlorine overdoses. A control system for nitrogen removal by breakpoint chlorination should include automatic analyzers to control chlorine dosage within a narrow range around the required values. Direct measurement of residual chlorine or indirect measurement of pH can be used to control breakpoint chlorination.

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are:

1. Established schedules for checking all connections for chlorine gas leaks. The piping system can be checked for chlorine leaks by using an ammonia solution or checking for the appearance of green copper scum around the edges of corroded metal at the joints.
2. Atmospheric chlorine leak detection equipment checked out and periodically calibrated.
3. Evaporator periodically checked for corrosion.
4. Inspect chlorine gas filter at 6 months intervals.
5. Chlorine pressure reducing valve regularly inspected. Every 2 to 3 years the spring opposing the silver diaphram will suffer fatigue and should be replaced. Every 5 years the entire assembly should be dismantled and the diaphram inspected for fatigue.
6. Chlorination system regularly inspected for restrictions between the cylinder and the chlorinator caused by impurities.
7. Chlorine Institute Emergency Kit to seal off leaking cylinders. Several units should be provided near the feed facility.
8. Gas diffusion devices in the contact basins periodically inspected to ensure that they are not clogged.
9. Bulk liquid chlorine storage tanks flow control valves in the dome of the tank inspected regularly. Provisions made to hydrostatically test the bulk liquid chlorine storage tank at 2 years intervals.
10. Rotameter tube and chlorine metering orifice removed from the chlorinator and cleaned at least once every 6 months.
11. Chlorine residual analyzer calibrated and maintained on a regular basis. In order for this equipment to perform effectively it must receive daily, weekly, and quarterly inspections.

12. Spare parts for the chlorination equipment: Spring, seals, and gaskets for diaphram assemblies; moving devices such as potentionmeters; safety devices dependent upon mercury switches; reversible electric motors, such as used to position the chlorine flow control orifice; motorized vacuum valves and other parts recommended by the chlorine equipment manufacturer should be maintained in inventory.

13. Established schedule for removal of scum and settled sludge from the chlorine contact basins.

Records

Recommended sampling locations and laboratory tests are shown in Figure 12-1. Other operation records should include:

1. Chlorine contact basin or plant influent flow measurement
2. Chlorine dosage in mg/l
3. Chlorine applied in pounds per day

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the performance of the chlorination process.

1. Orthotolidine color comparator and necessary test reagents.
2. Analytical balance
3. General laboratory glassware including volumetric flask, graduated cylinders, burets, beakers, pipettes, etc.
4. Test reagents including acetic acid, potassium iodide, standard sodium thiosulfate, starch indicator solution, and other reagents per "Standard Methods".

The EPA report entitled "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" provides a detailed listing of glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

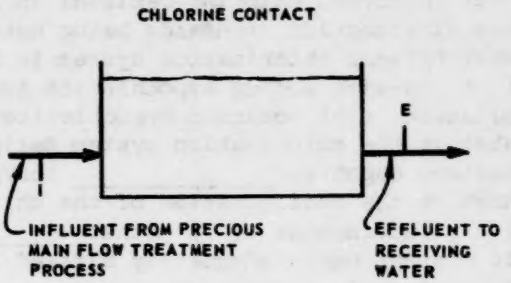
Sampling Procedures

Chlorine determinations be started immediately after sampling, avoiding excessive light and agitation. Samples to be analyzed for chlorine can not be stored. Samples for analyses should be collected in clean sample bottles and taken at a location which will provide a representative sample.

There are several laboratory procedures which are suitable for measuring chlorine residuals in wastewaters. These methods and their advantages and disadvantages are described in "Standards Methods for the Examination of Water and Wastewater".

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

DISINFECTION


CHLORINE CONTACT
E
I
INFLUENT FROM PRECIOUS MAIN FLOW TREATMENT PROCESS
EFFLUENT TO RECEIVING WATER

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	CHLORINE RESIDUAL	0-5	1/D	E	G	P C
	CHLORINE RESIDUAL	75	R	E	R	P C
OPTIONAL	COLIFORM	ALL	1/W	E	G	P
	FECAL COLIFORM	>5	1/W	E	G	P
	pH	ALL	1/D	I	G	H
	TEMP	ALL	1/D	I	G	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 12-1

Process Checklist - Chlorination

1. What is the flow to the chlorine contact basin?________________mgd avg. ____________ mgd peak
2. What are contact basin dimensions? ________________ length/feet, ________________ width/feet, ________________ depth/feet.
3. What is contact basin detention time?__________min. (at peak flow)
4. What is applied chlorine dosage?______________ mg/l
5. What is normal chlorine residual in basin effluent? ____________ mg/l
6. Are disinfection standards being met? ( ) Yes ( ) No
7. What type of chlorination system is being used?( ) chlorine cylinders ( ) on-site sodium hypochlorite generation ( ) sodium hypochlorite solution ( ) calcium hypochlorite solution?
8. What is the chlorination system design capacity?___________lbs/per/day maximum capacity?______________ lbs/per/day
9. What is the configuration of the chlorine contact basin? ( ) round ( ) rectangular ( ) other ________________
10. Is contact basin adequately baffled to minimize shortcircuiting? ( ) Yes ( ) No
11. How is chlorine introduced into the wastewater entering contact basin? ( ) perforated diffusers ( ) injector with single entry point ( ) other ____________
12. Are mechanical mixing provisions incorporated in the chlorine contact basin design? ( ) Yes ( ) No
13. Is plant equipped with automatic chlorine leak detectors with alarms in critical areas? ( ) Yes ( ) No
14. Is the ventilation system for chlorine cylinders storage and chlorination equipment rooms adequate? ( ) Yes ( ) No
15. How often are facilities checked? ( ) once per shift ( ) daily ( ) other ____________
16. Does the treatment plant maintain an adequate spare parts inventory? ( ) Yes ( ) No
17. What is the frequency of scheduled maintenance? Describe ________________ ____
18. Is the maintenance program adequate? ( ) Yes ( ) No. If no, what is the problem? ____ ____
19. Are proper safety precautions used? ( ) Yes ( ) No
20. Does the sampling program satisfy the recommendations? ( ) Yes ( ) No
21. Are operating records adequate? ( ) Yes ( ) No
22. Is the laboratory equipped to perform the necessary analyses? ( ) Yes ( ) No
23. What is the general condition of the chlorination facilities? ( ) good ( ) fair ( ) poor
24. What are the most common problems the operator has had with the chlorination process?____ ____ ____ ____ ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, EPA Report 430/9-78-001.

2. George Clifford White, Handbooks of Chlorination, Nostrand Reinhold Co. 1972.

3. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation, 1977.

4. Culp, Gordon L., and Culp, Russell L., Handbook of Advanced Wastewater Treatment, Van Nostrand Reinhold, 1977.

5. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-02-0328, June 1973.

6. Rand, M.C. et al, Standards Methods for the Examination of Water and Wastewater, American Public Health Association 14th edition, 1975.

13. OZONATION

Process Description

Ozone is an extremely powerful oxidizing agent which has been used principally in Europe for the disinfection of water supplies. When applied to wastewaters, ozone will oxidize many residual organic compounds, reducing the effluent BOD, COD, and color and adding dissolved oxygen to the final effluent. Unlike chlorine, ozone produces no residual materials which are toxic to aquatic life in the receiving stream and adds no dissolved solids.

Ozone is produced by passing air, oxygen enriched air, or pure oxygen between two electrodes across which an alternating high voltage potential is maintained. Figure 13-1 illustrates a basic configuration of an element common to the various types of ozone generators commercially available. This method of ozone production is inefficient. Only about 10% of the energy supplied is used to produce ozone. The remainder is lost as light, sound and heat. Ozone gas is unstable and within a very short time period decomposes to oxygen. The inability to store ozone requires that it must be produced at its point of use.

There are three basic types of commercially available ozone generators: the Otto plate, the tube and the Lowther plate. These are described in Reference 1.

Typical Design Considerations and Performance Evaluation

The design criteria and related ozone dosages for an ozonation system depends upon whether the ozone is to be applied for disinfection or as a tertiary treatment process for effluent polishing. Ozone dosages and required contact times are different for the two requirements.

A value of 200 fecal coliform/100 ml can usually be attained in secondary effluents using an ozone dosage of about 5 mg/l. Contact times may range from as little as 2 minutes to as much as 15 minutes. Five minutes appears to be adequate with proper dosages and with efficient contactor design. Standards calling for almost complete coliform removal (to 2 fecal coliform per 100 ml) may require dosages of 15 mg/l or more. For most cases, an ozone residual of 0.1 mg/l for 5 minutes is adequate to disinfect waters low in organics and free of suspended materials. The degree of pretreatment has a significant impact upon the effectiveness of ozone for disinfection. The presence of organic material exerts an ozone demand which can prevent maintenance of a killing residual. Also the presence of particulate material can shield organisms from the germicidal effects of ozone.

As a tertiary treatment process, ozone can reduce BOD, COD, color, turbidity and odor. Ozone dosages are widely variable depending upon particular treatment requirements. Contact times tend to be in a range similar to disinfection. With good mixing, a contact time of 5-10 minutes will achieve maximum oxidation of organics. Theoretically 3 mg/l of ozone will destroy about 1 mg/l of COD. Experimentally, it has been observed when applying ozone to alum coagulated and filtered secondary effluent that the COD was reduced from 36-41

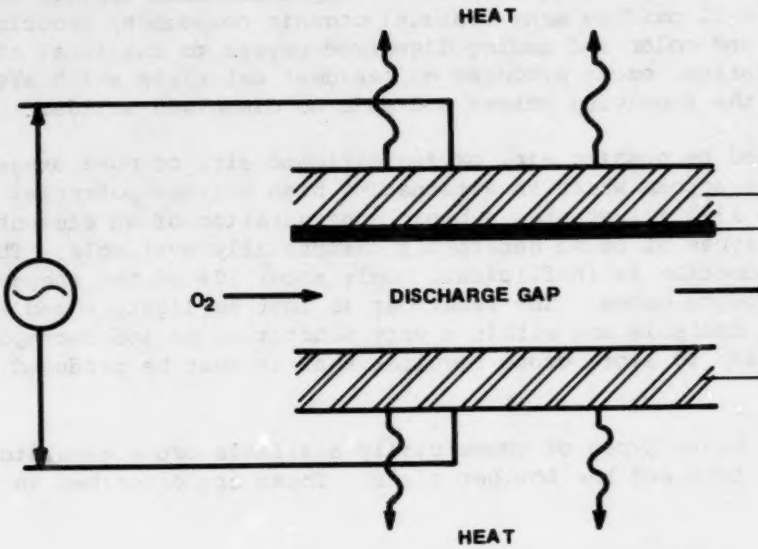

HEAT
ELECTRODE
DIELECTRIC
O_2
DISCHARGE GAP
O_3
ELECTRODE
HEAT

Figure 13-1. Basic ozonator configuration.

mg/l to 15-17 mg/l with 63-89 mg/l ozone. These data exhibit a COD to ozone ratio ranging from 2.6-3.7 which corresponds reasonably to the predicted ratio. Considering that a well treated secondary effluent has a COD range of 25-35 mg/l, a 50% reduction would require an ozone dosage ranging from 36 to 50 mg/l. For general design purposes the ozone system for polishing secondary effluent to the above standards should be capable of providing ozone dosages in excess of 50 mg/l.

The following example is for calculating ozone requirements.

Desired Dosage in contact basin	5 mg/l
Wastewater flow	10 mgd
Ozone concentration (%/wt)	3%
Feed gas	Oxygen

Determine required ozone production, lbs/day

lbs/day ozone = Dosage, mg/l x flow mgd x 8.33 lbs/gal
= 5 mg/l x 10 mgd x 8.33 lbs/gal
= 417 lbs/day O_3

Determine feed gas (oxygen) flow, SCFM

$$@\ 3\%\ O_3,\ \text{lbs of } O_2 \text{ required per day} = \frac{417 \text{ lbs/day } O_3}{0.03 \text{ lbs } O_3/\text{lbs } O_2}$$

$$= 13{,}900 \text{ lbs } O_2/\text{day}$$

At 70°F and 14.7 psia, 1 lb O_2 has volume of 12.08 ft^3

$$\text{Volume SCFM} = 13{,}900\ \frac{\text{lbs } O_2}{\text{day}} \times \frac{12.08\ ft^3}{\text{lb}} \times \frac{1 \text{ day}}{24 \text{ hrs}} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

= *117 scfm oxygen flow

*Changes in temperature, pressure or feed gas oxygen concentration affect required generator feed gas flow. Appropriate correction factors must be applied to determine correct values. Refer to manufacturer's instruction manuals.

Process Control

The application of ozone to a wastewater, whether it be for disinfection or for effluent polishing, requires close control to ensure effective performance. Production of ozone which is related to the flow of water under treatment and its dosage requirements may be controlled manually or automatically by probe and relay. The automatic dosage control loop system is preferred since it compensates for changes in flow and ozone demand to provide a preset ozone residual. Starting up sequences are important and require establishment of exact procedures and timing. A centralized control panel containing all initiating controls, process performance indicators, inner locks and other safeguards are generally incorporated in any ozone system.

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are:

1. Schedules established for checking electrical and gas connections for tightness. The piping system can be checked for ozone leaks by holding paper towels soaked in potassium iodide solution to the connectors or by applying an approved leak detection material.

2. Atmospheric ozone leak detection equipment check-out and calibration. Has a specific schedule for this attention been established?

3. Ozone cells checked for accumulations of grease and dirt.

4. Gas diffusion devices in the contact basins regularly inspected to ensure that they are performing properly. Porous diffusers may become clogged with materials percipitated from solution requiring acid or caustic cleaning to remove.

5. Basin covers periodically checked for gas leaks.

6. Ozone destruction devices (single pass systems) checked for effective functioning.

7. Instrumentation for measuring ozone concentrations of ozonator output and the dew point analyzer on the feed gas supply periodically calibrated.

8. Spare parts inventory should include: SCR rectifier and control circuit fuses, fan belt set, fan bearing, fan belt grease, fan starter, thermal overloads, various relays for key electrical components, replacement cell module, high temperature alarms, and spare parts for ozone leak detection instrumentation and for other monitoring instrumentation. Some variation will occur with the different styles of generators.

Records

Recommended sampling locations and laboratory tests are shown in Figure 13-2. Other operating records should include:

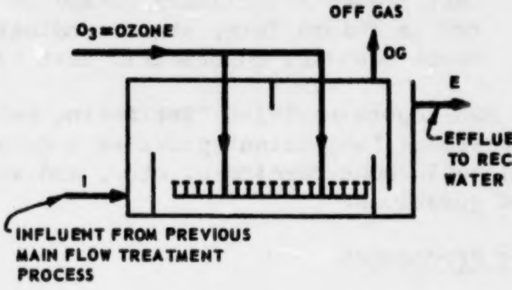
1. Ozone contact basin influent flow
2. Ozonizied gas flow to contact basin
3. Flow rate of off-gas from contact basin

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the performance of the ozonation process:

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

OZONATION


OFF GAS
O_3=OZONE
OG
E
EFFLUENT TO RECEIVING WATER
I
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	OZONE RESIDUAL	ALL	R	E	R	P,L
	OZONE CONCENTRATION	ALL	Mn	O_3	Mn	P,C
	OZONE CONCENTRATION	ALL	Mn	OG	Mn	P,C
	COLIFORM	ALL	1/W	E	G	P
	FECAL COLIFORM	>5	1/W	E	G	P
OPTIONAL	pH	ALL	1/D	E	G	H
	TEMP	ALL	1/D	E	G	H
	DO	ALL	1/W	E	G	H
	BOD	ALL	1/W	E	G	H
	COD	ALL	1/W	E	G	H
	TURBIDITY	ALL	1/W	I E	G	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

O_3= OZONE GAS FLOW
OG= CONTACT BASIN OFF GAS

C. METHOD OF SAMPLE

24C= 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 13-2

1. Analytical balance
2. Wet test drum meter with associated barometer and thermometer
3. Gas washing bottles (2)
4. Dewpoint meter for monitoring moisture content of feed gas
5. General laboratory glassware including volumetric flasks, graduated cylinders, burets, beakers, pipettes, etc.
6. Tygon tubing
7. Test reagents including potassium iodide solution, sulfuric acid, sodium thiosulfate, starch indicator solution, potassium dichromate
8. Ozone residual colormetric test kit

The EPA report entitled "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" provides a detailed listing of glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Effluent residual ozone determinations must be performed immediately because samples can not be preserved or stored due to the instability of the residual. Samples should be collected in a manner so as to minimize aeration. There are three testing methods described in Standard Methods.

Sidestreams

The off-gas from the ozone contact basin can be considered a sidestream. In a single pass, once-through system, the ozone in the waste gas is destroyed by heat or chemicals, or catalyic decomposition prior to venting to atmosphere. In the closed loop system, the off-gas is recycled back to the ozone generation equipment and reused.

In some applications, the introduction of ozone produces foam and scum which collects on the contact basin and must be removed. The quantity of this material is, however, very small and the removal requirements are minimal. The best way of controlling of foam on contact basins is to reduce it with water sprays.

Process Checklist - Ozonation

1. What is flow through ozone contact basin ____________ mgd avg? ____________ mgd peak?
2. What are contact basin dimensions? length ________ feet, width ________ feet, depth ________ feet
3. What is contact detention time? __________ minutes at __________ mgd?
4. What is applied ozone dosage __________ in mg/l?
5. What is normal ozone residual in basin effluent __________ mg/l?
6. Are disinfection standards being met? ( ) Yes ( ) No
7. What type of ozone generation equipment? ( ) plate style ( ) tube style ( ) other __________
8. What is ozone generator design capacity __________ lbs/day, maximum capacity __________ lbs/day?
9. Ozone generation equipment uses ( ) air, oxygen enriched air ( ) pure oxygen ( ) as feed gas?
10. What type ozone contactor? ( ) gravity feed covered basin ( ) packed tower ( ) Other __________
11. Is ozonation system ( ) Once through ( ) closed loop?
12. How is ozone introduced into contactor? ( ) porous diffusers ( ) injectors ( ) turbine aerators ( ) other?
13. Are residual ozone determinations made with ( ) continuous analyzers or by ( ) laboratory tests?
14. Is plant equipped with automatic ozone leak detectors with alarm in critical areas? ( ) Yes ( ) No
15. Is ozone generator room adequately ventilated? ( ) Yes ( ) No
16. How often are facilities checked? ( ) once per shift ( ) daily ( ) other __________
17. Does the mechanical equipment have an adequate spare parts inventory? ( ) Yes ( ) No
18. What is the frequency of scheduled maintenance? Describe ______________________________
    ____
19. Is the maintenance program adequate? ( ) Yes ( ) No. If no, what is the problem? ______________________________
    ____
20. Are proper safety precautions used? ( ) Yes ( ) No
21. Does the sampling program satisfy the recommendations? ( ) Yes ( ) No
22. Are operating records adequate? ( ) Yes ( ) No
23. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
24. What is the general condition of the ozonation process? ( ) good ( ) fair ( ) poor
25. What are the most common problems the operator has had with the process?
    ____
    ____
    ____
    ____

References

1. Culp, G.L. and Folks Heim, N., Field Manual for Peformance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, EPA Report 430/9-78-001.

2. Rosen, H.M., "Ozone Generation and It's Relationship to the Economical Applications of Ozone and Wastewater Treatment", Chapter VI, Ozone in Water and Wastewater Treatment, Ann Arbor Science Publishers Incorporated 1972.

3. Kinman, R.N., "Ozone and Water Disinfection" Chapter VII, Ozone in Water and Wastewater Treatment, Ann Arbor Science Publishers Incorporated 1972.

4. Diaper, E.W.J., "Practical Aspects of Water and Wastewater Treatment by Ozone" Chapter VII, Ozone in Water and Wastewater Treatment, Ann Arbor Science Publishers Incorporated 1972.

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6. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328, June 1973.

7. Union Carbide Corporation, Linde Division, Operation and Maintenance of the Union Carbide LG-90 Ozone Generator Tonawanda, N.Y. 1977.

8. Stopka, Karel, "Ozone Plant Improves Efficiency and Economy of Wastewater Treatment", Water and Sewage Works, April 1978.

14. FILTRATION

Process Description

The filtration process is used to remove or reduce the suspended or colloidal matter from a liquid stream by passing the water through a bed of graded granular material. The granular material can be sand, gravel, coal, garnet or similar materials. The main purpose of filtration is meet more stringent discharge standards and improve disinfection efficiency and reliability. Filtration is used to remove BOD, COD, turbidity, phosphorus, virus, asbestos, heavy metals and others from secondary or tertiary effluent. It is always used ahead of granular activated carbon contactors to protect against fouling and improve the adsorption efficiency. Filtration is frequently installed following chemical treatment processes to remove flocculant materials not removed in the clarifiers.

Filters are classified in many ways. They can be described according to the direction of flow through the bed, that is, downflow, upflow, biflow, radial flow, horizontal flow, fine to coarse, or coarse to fine. They may be classed according to the type of filter media used, such as sand, coal (or anthracite), coal-sand, multilayered, mixed media, or diatomaceous earth. Filters are also classed by flow rate. Slow sand filters operate at rates of 0.05-0.13 gpm/ft^2, rapid sand filters operate at rates of 1-2 gpm/ft^2 and high rate filters operate at rates of 3-15 gpm/ft^2. They can also be classed by the flow characteristics of filters which can be pressure or gravity flow. Filters used for wastewater treatment are predominantly downflow, multi-media, high rate filters that can have either gravity of pressure flow characteristics.

Because of the high loading rates currently used in filtration systems (about 30 times the rate of slow sand filters) they capture more solids in less time and must be cleaned more often. The filter is cleaned by reversing the flow through the media ("backwashing"). The upward backwash rate must be high enough that the media particles are suspended and the wastewater solids and captured materials are washed from the bed. These backwash wastewaters (usually less than 5% of the wastewater flow treated) are stored in an equalization tank and then recycled to the wastewater treatment plant for processing.

Typical Design Considerations

The principal criteria by which filters are sized are related to the flow characteristics, gravity or pressure, and the type, size and depth of the filtering media. Once these have been established, the loading, backwashing and surface washing rates can be established. These items are briefly discussed in the following paragraphs:

Filter media designs are usually either dual media filters which consist of 15 in. of coal (about 1.8 mm in diameter) and over 15 in. of sand (0.55 mm) or mixed media which consists of about 16 in. of coal, 9 in. of sand, and 4 in. of garnet.

The most common filtration rates used in wastewater treatment range from 3 to 6 gpm/sq ft of filter area. This range in loading rate is applicable to both the dual media and mixed media configurations.

Backwash systems for filters usually are operated at rates in the range of 15 to 20 gpm/sq ft for 5-10 min. The backwash water is returned to the headworks for treatment.

Typical Performance Evaluation

The filtration process is evaluated by the quality of the filtered water measured in terms of suspended solids or turbidity. Other factors include:

- Rate of headloss build-up, feet/hour
- Water application rate
- Influent characteristics
- Filtration media characteristics
- Filter backwash system
- Filter surface wash system

Of these factors, the most important is the quality of the influent to the filter. When filtering secondary effluent, if the biological system always operates well, good filter performance can be expected. However, if the biological system is frequently upset, filtration will be much more difficult. Performance evaluation may be conducted as described below.

1. Collect the required base information.

   Plant flow rate = 15 mgd
   BOD in influent to filter = 20 mg/l
   Suspended solids in influent to filter = 25 mg/l
   BOD in filter effluent = 10 mg/l
   Suspended solids in filter effluent = 3 mg/l
   Filter size = 22 ft x 24 ft
   Number of filters = 4
   Backwash flow rate = 7920 gpm
   Backwash duration = 7 min
   Frequency of filter backwash = once each 12 hours
   Headloss to backwash (preset condition) = 10 feet

2. Compute the filter area and rate of filtration under normal conditions

   $$\text{Plant flow rate} = \frac{15 \text{ mgd} \times 10^6}{1440 \text{ min/day}} = 10{,}417 \text{ gpm}$$

   $$\text{Filter area} = 4 \times 22 \times 24 = 2{,}112 \text{ sq ft}$$

   $$\text{Filtration rate} = \frac{10{,}417 \text{ gpm}}{2{,}112 \text{ sq ft}} = 4.93 \text{ gpm/sq ft}$$

This system is within the range of filtration rates normally used, which is 3 to 6 gpm/ft^2.

3. Compute the rate of backwash and the volume used.

Rate of backwash $= \frac{7920}{2112/4 \text{ filters}} = 15$ gpm/sq ft per filter

Flow through each filter $= \frac{15 \text{ mgd} \times 10^6}{4 \times 1440 \text{ min/day}} = 2604$ gpm

Volume of backwash water = 7920 gpm x 7 min/backwash x 2 day x 4 filters
= 443,520 gallons/day

Volume of water through filters $= \frac{(1440 - 2 \times 7) \times 2604 \times 4}{10^6}$

$= 14.85$ mgd

Percent backwash water $= \frac{0.433}{14.85} \times 100 = 3\%$

The backwash rate of 15 gpm/sq ft^2 falls at the lower end of the normal range for backwashing of 15 to 20 gpm/ft^2. The backwash percentage of 3% is within the desirable range of backwash usage of 1 to 5%.

4. Compute the percentage of BOD and suspended solids removals.

Percentage BOD removal $= \frac{20 - 10}{20} = 50\%$

Percentage suspended solids removal $= \frac{25 - 3}{25} = 88\%$

5. Characterize the influent water to the filter as being activated sludge, trickling filter, chemical clarification or some other process effluent. Using the average values developed above, compare them to the average values expected values presented in Table 14-1. These values are for mixed media filters and were developed using data at several operating facilities. When treating chemically coagulated and settled effluent, the filter effluent should be less than 1 turbidity unit.

Process Control

The control considerations for the filtration process depend almost totally on the filter aid facilities provided. These include polymer and chemical conditioners to be added ahead of the filters. Other controls include adjustment of the headloss to backwash value and the length of the backwash runs. These are discussed in more detail in Reference 1.

Maintenance Considerations

The evaluator should study the maintenance program to determine whether the following items are included (in addition to general maintenance management discussed earlier).

1. Spare parts inventory should include at least the following items: one set of each type of bearing for pumps, grease seals, one set of all gaskets, mechanical seals, washers or sheaves for adjusting pump impellers, nozzles for surface wash system and underdrain system, control solenoid and some volume of the filter media.

TABLE 14-1. DESIGN CRITERIA FOR ORANGE COUNTY WATER DISTRICT OPEN GRAVITY, MIXED MEDIA FILTER SYSTEM

Dimensions:	4 filters each 22 ft x 24 ft (plan area) media depth = 30 in

Bed construction:

Media	Depth (in)	Specific gravity	Grain size range (mm)
Anthracite coal	16.5	1.6	0.84-2.00
Silica sand	9	2.6	0.42-0.84
Garnet sand	4.5	4.0	0.18-0.42
Garnet gravel	1.5	4.0	1
Garnet gravel	1.5	4.0	2.00-4.76
Silica gravel	2	2.6	3.18-6.36
Silica gravel	2	2.6	6.36-12.72
Silica gravel	2	2.6	12.72-19.08

Surface hydraulic loading rate:	4.93 gpm-sq ft at 15 mgd (2604 gpm per filter)
Max operating headloss:	10 ft

2. Daily inspection of the rotary surface washers to insure they are free to rotate and the nozzles are not plugged? In gravity filters, the washing operation should be monitored for any plugged orifices.

3. Inspection in each shift to check the calibration of the effluent turbidimeters and any other remote recording or instrumentation.

4. Recorder charts on flow, headloss, and turbidity meters changed routinely and the recorder ink supply checked at each chart change.

5. System is monitored routinely and that the filters are not operating out of their anticipated operating range.

6. Regular readings of backwash pumping times are recorded from elapsed time meters. These can be used for scheduling maintenance work and also to insure that backwash cycles are correct.

7. Periodic performance tests run on each pumping unit to insure that it is operating along the same pump curve as supplied at the time of purchase of the pumping unit.

Records

The recommended sampling and laboratory tests are shown in Figure 14-1 for the filters. The same tests are performed on all types of filters.

Other operating records should include the following:

1. Influent flow to the filters
2. Backwash flow rate and duration
3. Surface wash flow rate and duration
4. Filter run time or frequency of backwash
5. Headloss through filter as a function of time
6. Filter aid type and dosage

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the filtration system.

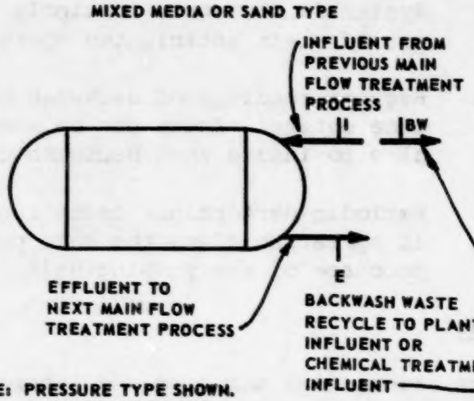
1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Dessicator
6. Turbidimeter

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TURBIDITY	ALL	R	E	R	P
	BOD	ALL	1	BW	G	P[2]
	SUSPENDED SOLIDS	ALL	1	BW	G	P
	FLOW	ALL	R	BW	R	P[2]
OPTIONAL	BOD	ALL	2/W	I E	24C	H
	SUSPENDED SOLIDS	ALL	2/W	I E	24C	H

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

FILTRATION


MIXED MEDIA OR SAND TYPE
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
I
BW
E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
BACKWASH WASTE RECYCLE TO PLANT INFLUENT OR CHEMICAL TREATMENT INFLUENT

NOTE: PRESSURE TYPE SHOWN. GRAVITY TYPE HAVE SIMILAR FLOW STREAMS.

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
BW = BACKWASH

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. WHEN BACKWASHING
2. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 14-1

Sampling Procedures

Samples should be collected from sampling taps in the influent and effluent lines for pressure filters and from the influent distribution trough and backwash storage well in the case of gravity filters. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent lines or storage tank should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The only sidestream associated with the filtration process is the wastewater associated with backwashing or cleaning the filters. The volume of water is normally in the range of 1 to 5 percent of the volume of water passing through the filter, and is most frequently found to be about 2 to 3 percent of the throughput volume.

The wastewater from backwashing the filters contains suspended solids in the range of 100 to 1000 mg/l, with an average value of about 300 mg/l. The water may be discharged to a settling tank where the settled solids are withdrawn and pumped to the solids handling facility and the supernatant recycled to the treatment plant. In many cases, the backwash water is all recycled to the treatment plant at a controlled rate from a storage tank.

Process Checklist - Filtration

1. What is flow through filters __________ mgd avg. __________ mgd max. __________ mgd min?
2. Type of filters ( ) gravity ( ) pressure, number of units ________ and capacity of each filter __________
3. What is type of filter media? ( ) sand ( ) dual media ( ) mixed media ( ) multi-media ( ) diatomaceous earth ( ) other ________
4. What is surface loading rate?__________ gpm/ft^2
5. What is backwash rate?__________ gpm/ft^2
6. What is surface wash rate?__________ gpm/ft^2 and pressure __________ psi
7. Type of control system? ( ) constant flow ( ) headloss ( ) time ( ) turbidity of effluent ( ) total gallons filtered ( ) other ____
8. Are all automatic valves operating correctly? ( ) Yes ( ) No
9. Are the valves sequencing (opening and closing in order) correctly? ( ) Yes ( ) No
10. Is there a coagulant aid (filtration aid) system? ( ) Yes ( ) No If yes, what type ______________________________
11. Is the chemical aid system operating? ( ) Yes ( ) No If no, explain ______________________________
12. What are the dimensions of the filter?______________________________
13. Operation of the system is? ( ) Automatic ( ) Manual ( ) semi-automatic ( ) Other ______________________________
14. Are all pumps operating? ( ) Yes ( ) No. If no, what is the problem? ______________________________
15. Does the mechanical equipment have an adequate spare parts inventory? ( ) Yes ( ) No
16. Is the filter building adequately ventilated? ( ) Yes ( ) No
17. How often are facilities checked? ( ) Once per shift ( ) Daily ( ) Other ____________________
18. What is frequency of scheduled maintenance?______________________________
19. Is the maintenance program adequate? ( ) Yes ( ) No If no, what is problem ______________________________
20. What is the general condition of the filtration process? ( ) good ( ) fair ( ) poor
21. What are the most common problems the operator has had with the filtration systems? ______________________________

____

____

____

____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

7. Culp, Gordon L., and Culp, Russell L., New Concepts in Water Purification, Van Nostrand Reinhold, 1974.

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15. MICROSCREENING

Process Description

A microscreen is a mechanical filter process used to remove suspended solids from secondary effluent. The equipment consists of cylindrical drums horizontally mounted in a two-compartment concrete tank. Each drum is covered with a woven fabric which serves to trap the solids as the wastewater flows through it. The drum is usually submerged about two-thirds underwater, with solids being retained on the inside surface as it slowly rotates. The screen is equipped with a backwashing unit to remove the accumulated solids. Washwater is collected in a hopper or trough mounted inside the screen and is recycled to another process. The water used for backwashing is recycled screened effluent, constituting about 3 to 5 percent of the total screened flow.

Table 15-1 shows typical values for microscreen and backwash design parameters for solids removal from secondary effluents. Similar values would apply to direct microscreening of good quality effluent from trickling filters or rotating biological contactors where the microscreens replace secondary settling tanks.

Typical Performance Evaluation

Microscreens with 23-μ apertures can be expected to remove 70 to 80 percent of the suspended solids in activated sludge effluent and 60 to 70 percent of the BOD. With a larger aperture (35 μ) 50 to 60 percent of the suspended solids and 40-50 percent of the BOD would be removed. Detailed performance factors are given in Reference 1.

Process Control

Except for drum speed there is little the operator can control with the microscreening process. If the drum travels too fast, it will not do an effective screening job and may cause excess wear on the mechanical parts. If it runs too slowly, the fabric will become clogged and the head between the influent and the effluent may become so great that the fabric breaks. A clogged screen may cause the influent to bypass the microscreen.

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are:

1. Tears in screen are repaired or replaced as soon as possible.
2. Backwash nozzles cleaned on a regular basis.
3. Drum is periodically cleaned of accumulated grease and oil and algae or slime growths.

TABLE 15-1. MICROSCREEN DESIGN PARAMETERS

Item	Typical Value	Remarks
Screen mesh	20-25 microns	Range 15-60 microns
Submergence	75 percent of height 66 percent of area	
Hydraulic Loading	5-10 gpm/sq ft of submerged drum square area	
Headloss (H_L) through screen	3-6 in.	Maximum under extreme condition 12-18 in. Typical designs provide for overflow weirs to bypass part of flow when head exceeds 6-8 in.
Peripheral Drum Speed	15 fpm at 3 in. (H_L) 125-150 fpm at 6 in. (H_L)	Speed varied to control extreme maximum speed 150 fpm.
Typical Diameter of Drum	10 ft	Use of wider drums increases backwash requirements.
Backwash Flow and Pressure	2 percent of throughput at 50 psi 5 percent of throughput at 15 psi	

4. Spare parts inventory should contain the following: replacement mesh for rotating drum, gears and motors for rotating drives, backwash nozzles, etc.

Records

Recommended sampling and laboratory tests are shown on Figure 15-1.

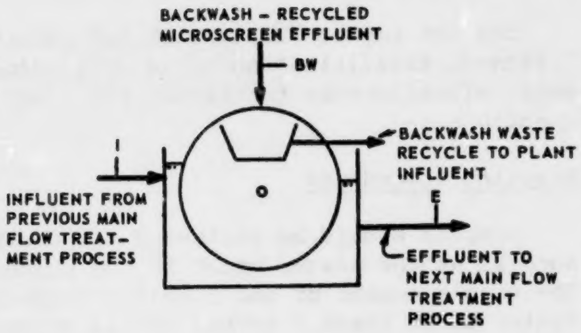
Other operating records should include:

1. Backwash flow rate.
2. Percent of throughput used for backwash.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

MICROSCREENING

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TURBIDITY	ALL	R	E	R	P
	BOD	ALL	1	BW	G	P[2]
	SUSPENDED SOLIDS	ALL	1	BW	G	P
	FLOW	ALL	R	E	R	P[2]
OPTIONAL	BOD	ALL	2/W	E	24C	H
	SUSPENDED SOLIDS	ALL	2/W	I E	24C	H


BACKWASH – RECYCLED MICROSCREEN EFFLUENT
BW
BACKWASH WASTE RECYCLE TO PLANT INFLUENT
I
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
BW = BACKWASH

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. WHEN BACKWASHING
2. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 15-1

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the microscreening.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be consulted for any detailed questions.

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed such as at the center point of the channel of flow where velocities are high. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channels should be collected near the discharge point to insure well mixed specimens. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The backwash from microscreening constitutes about 2 to 3 percent of the through-put and has a suspended solids concentration of 700 to 1000 mg/l. It is ordinarily returned to the headworks of the plant and does not present any particular operating problems. Because there is a certain amount of grease and oil mixed in this flow, keeping the return lines clear is important to proper plant operations.

Process Checklist - Microscreens

1. What is the volume of flow to the microscreens _____mgd average; _______ mgd peak?
2. Type of filter fabric ______________; mesh aperture ________________.
3. Number of microscreens ___________; capacity of each unit _________; operating loading rate ________________ gpm/ft^2.
4. Backwash rate _____________. Frequency of backwashing ___________. Location of backwash recycle __________________.
5. Are all microscreen and backwash units operating properly? ( ) Yes ( ) No
6. Does filter mesh appear to be clogged in one particular spot? ( ) Yes( ) No. Are all backwash nozzles spraying properly?( ) Yes ( )No
7. Is backwash collection trough adequate to collect solids and backwash flow ( ) Yes ( ) No. If not, would adjusting it's position result in proper collection. ( ) Yes ( ) No. Other ________________
8. Does backwash water flow freely to recycle point? ( ) Yes ( ) No
9. Does filter fabric show signs of wear? ( ) Yes ( ) No. Are there unrepaired tears in it? ( ) Yes ( ) No
10. Is there a accumulation of slime or algae on filter mesh? ( ) Yes ( ) No Grease or oil? ( ) Yes ( ) No
11. If multiple units are used, is flow distributed evenly? ( ) Yes ( ) No
12. Is all mechanical equipment operating properly? ( ) Yes ( ) No
13. How often is facility checked? ( ) Once per shift ( ) Daily ( ) Other ____________________
14. Frequency of maintenance inspections by plant personnel _________/year.
15. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ____
16. Does the sampling program meet the recommendations? ( ) Yes ( ) No
17. Are operating records adequate? ( ) Yes ( ) No
18. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
19. What is the general condition of the microscreening facilities? ( ) Good ( ) Fair ( ) Poor
20. What spare parts are stocked?____
21. What are the most common problems the operator has had with the filtration systems? ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

3. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

4. State of Virginia O&M inspection form.

5. Hazen and Sourfer Inc., Process Design for Suspended Solids Removal, EPA Technology Transfer (January 1975).

6. Culp, Russell L., Wesner, G. M., and Culp, Gordon L., Handbook of Advanced Wastewater Treatment, Van Nostrand Reinhold, 1978.

16. ACTIVATED CARBON ADSORPTION

Process Description

The activated carbon adsorption process is used to reduce the concentration of the soluble or dissolved organic matter in the wastewater. This process is normally used in one of two treatment schemes: (1) As an advanced wastewater treatment (AWT) process following a conventional biological treatment system; or (2) in conjunction with independent physical-chemical (IPC) treatment processes.

When used as an AWT process, the activated carbon process follows biological treatment, or sometimes chemical coagulation and sedimentation. Filtration normally precedes the activated carbon process to protect the system from fouling with suspended matter in the water. Biological systems can remove the majority of organic materials, but not the more complex soluble organic material. These organics can be removed by the activated carbon.

When the activated carbon adsorption process is used as an IPC process, it provides the only method for organic removal. In an IPC treatment system, the raw wastewater undergoes preliminary treatment, chemical coagulation and clarification, and filtration before carbon treatment. This treatment scheme removes a greater percentage of organics than biological secondary treatment alone, but not as much as when used as an AWT process.

Wastewater treatment with activated carbon involves two process operations, a contact system, and a carbon regeneration system. The water passes through a container filled with carbon granules or a carbon slurry. Organic impurities are removed from the water by adsorption onto the carbon. The contactors are either open concrete gravity-type systems, or steel pressure containers suitable for either upflow or downflow operation. Upflow operation occurs when the water enters the bottom of the pressure contactor and flows upwards through the carbon to exit at the top. Downflow is simply the reverse operation.

After the water has passed through the carbon beds for a period of time, it loses its capacity to adsorb the organics and must then be regenerated. The regeneration system is a furnace in which the carbon is placed and heated. The regeneration process is described in detail in Section 40 of this manual. The heat drives off the organic material that was adsorbed onto the carbon, and "reactivates" the carbon for continued use in the treatment system. About 5 to 10 percent of the carbon is lost during regeneration and must be replaced with new, fresh carbon.

The activated carbon that is used for wastewater treatment is either granular or powdered.

Typical Design Considerations

Activated carbon adsorption systems are chosen based on their location in an overall treatment system and on the estimated organic removal efficiency that is required. The type of carbon system used depends on the other treatment processes and the topography of the plant site.

Sizing of the unit is based on four factors: the contact time, the hydraulic loading rate, the carbon depth, and the number of contactors. Typical contact times range from 15 to 40 min, depending on the strength of the wastewater and the required effluent quality, and are normally selected after pilot plant testing.

Hydraulic loading rates vary from 3 to 12 gpm/ft^2 of cross-sectional carbon area for upflow contactors and from 2 to 5 gpm/ft^2 for downflow contactors. The upflow contactors must also include an allowance for the carbon bed expansion during operation. Typical expansion percentages for upflow contactors are given in Figure 16-1.

The depth of the carbon contactors ranges from 10 to 30 feet. The bed depth is normally determined from the surface area and the contact time.

The number of contactors depends on the treatment processes preceding them. The system must produce the required effluent quality with one unit out of operation. There should always be a minimum of two contactors.

Typical Performance Evaluation

Activated carbon contactors can be evaluated by using plant operational data and contactor characteristics. The following is an example of the step-by-step procedures for evaluating the performance of an activated carbon adsorption system:

1. Define the dimensions and design data for the carbon system.

Upflow Contactor
Pretreatment: Filtered Secondary Effluent
Column Flow Rate = 650 gpm
Column Diameter, D = 12 ft
Column Area, $A = (\pi/4)D^2$ = 113 sq ft
Carbon Depth = 26 ft 2 in. (312 in.)
Carbon Volume, V=A x Depth = 22,140 gal

2. Determine the contact time of the carbon column.

$$\text{Contact time (min)} = \frac{\text{Volume occupied by carbon in gal}}{\text{Flow rate in gpm}}$$

$$= \frac{22{,}140}{650}$$

$$= 34 \text{ min}$$

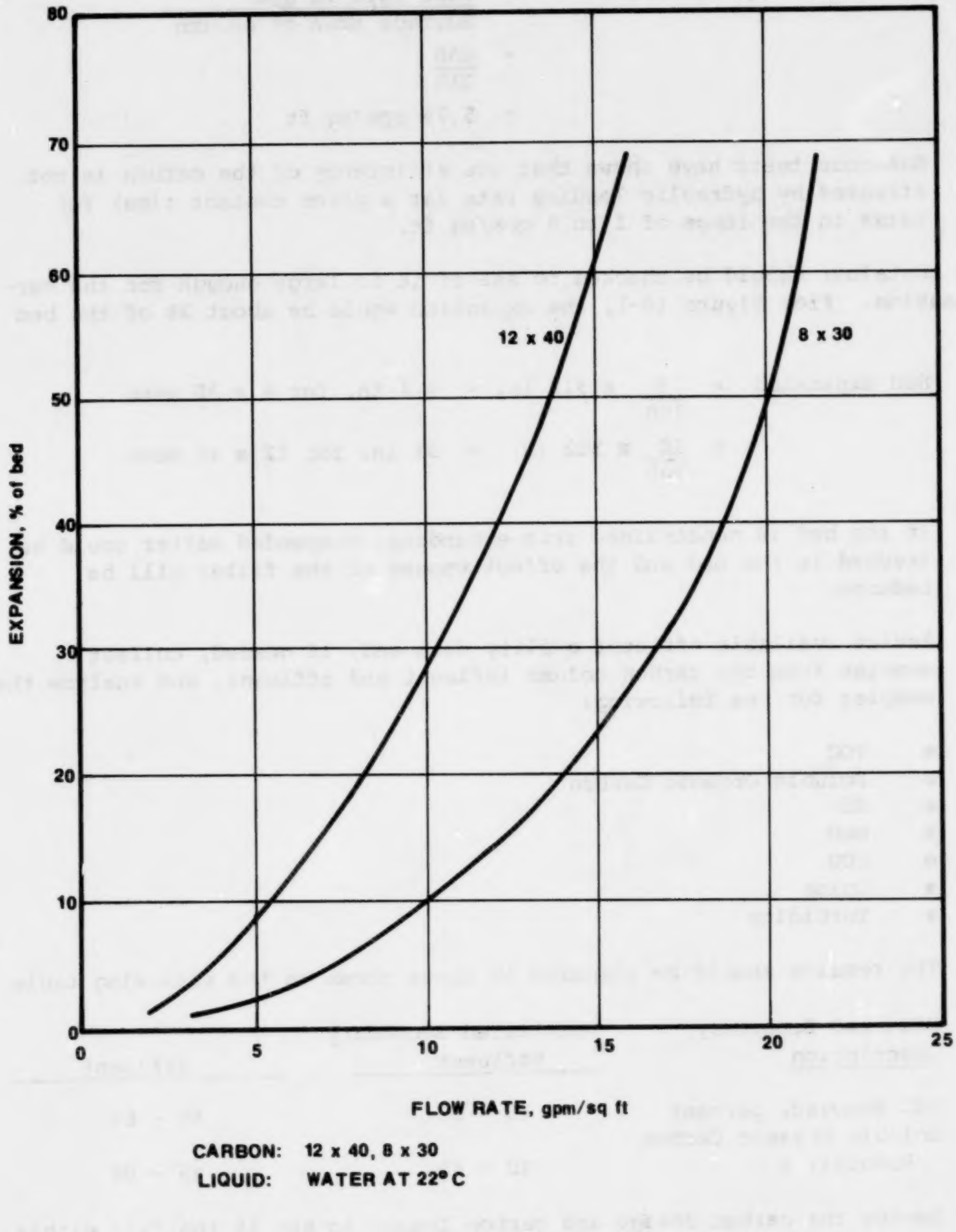


Figure 16-1. Expansion of carbon bed at various flow rates.

3. Determine the hydraulic loading rate.

$$\text{Hydraulic loading rate} = \frac{\text{Flow rate in gpm}}{\text{Surface area of column}}$$
$$= \frac{650}{113}$$
$$= 5.75 \text{ gpm/sq ft}$$

Numerous tests have shown that the efficiency of the carbon is not affected by hydraulic loading rate (at a given contact time) for rates in the range of 2 to 8 gpm/sq ft.

The container should be checked to see if it is large enough for the carbon expansion. From Figure 16-1, the expansion would be about 3% of the bed depth.

$$\text{Bed expansion} = \frac{3}{100} \times 312 \text{ in.} = 9.4 \text{ in. for } 8 \times 30 \text{ mesh}$$
$$= \frac{10}{100} \times 312 \text{ in.} = 31 \text{ in. for } 12 \times 40 \text{ mesh}$$

If the bed is constrained from expanding, suspended matter could be trapped in the bed and the effectiveness of the filter will be reduced.

4. Review available effluent quality data and, if needed, collect samples from the carbon column influent and effluent, and analyze the samples for the following:

- TOC
- Soluble Organic Carbon
- SS
- BOD
- COD
- Color
- Turbidity

The results should be compared to those shown in the following table.

Filtered Secondary Description	Unfiltered Secondary Effluent	Effluent
TOC Removed, percent	45 - 55	50 - 60
Soluble Organic Carbon Removal, %	40 - 45	45 - 50

6. Review the carbon dosage and carbon losses to see if the fall within typical design ranges. The importance of carbon dosage is described in the section on carbon regeneration (Section 40) and is not discussed here.

Process Control

The major control variations relate to the rate of flow through the contactors, the contact time, and the number of contactors in operation. These are interrelated, because adjustment of one of these control options changes the other two. It is important to avoid excessive contact times to prevent excessive biological growth which fouls the bed and results in a strong odor. This often occurs at the startup of a new plant when the flows are low. Maintaining the contact time and rate of flow through the bed within the typical ranges should result in efficient operation of the system.

The carbon dosage can be adjusted either upwards or downwards to optimize treatment efficiency. The upper limit is governed by the capacity of the regeneration system. If lower carbon doses can be used to achieve the desired effluent quality, the operating costs for regeneration will be less.

The rate of adsorption of organics found in municipal wastewater usually increases as the pH of the water decreases. Adsorption is very poor at pH values above 9.0. High pH wastewaters should be neutralized before carbon adsorption, and the influent pH should be kept fairly constant. A sudden, upward shift in pH can lead to desorption of organics and an increase in effluent COD.

Treating water that has high turbidity will plug carbon pores and result in the loss of carbon capacity. Thus, special attention should be given to the control of processes upstream of the carbon columns. The adsorptive capacity and service life of the carbon can be maximized by applying to the carbon water that has been carefully pretreated to the highest practical clarity.

Maintenance Considerations

Proper maintenance of a facility is an important function to insuring efficient, troublefree operation. The features of a good maintenance program are listed below. These considerations are to be used in conjunction with general maintenance management discussed earlier.

1. Spare parts inventory should include at least one set of each type of bearing, grease and water seals, all necessary gaskets for replacement of parts, influent and effluent strainers or underdrain systems.
2. Visual inspection each shift of the activated carbon process equipment to check the equipment for misalignment, excessive noise, unequal loading of the contactors, excessive pressures in pressure contactors.
3. Pressurized containers checked regularly to insure their integrity against failure.
4. All non-operating equipment, such as by-pass valves, being operated every month to test for operability.

5. Sample lines flushed regularly to flush out material, such as carbon fines, that may have entered the lines.

Records

The recommended sampling and laboratory tests are shown in Figure 16-2 for the activated carbon adsorption system.

Other operating records should include the following:

1. Influent flow rate
2. Carbon dosage in lbs per million gallons.
3. The amount of COD removed per pound of carbon
4. The contact time
5. Frequency of backwashing, if also used as a filter

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the activated carbon adsorption system.

1. Reflux apparatus to perform COD tests
2. Colorimeter
3. Turbidimeter

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected from the influent and effluent channels of each gravity contactor as well as the clear well or effluent channel, which has the combined flows. For pressure contactors, the samples are taken from taps in the influent and effluent pressure feed lines as well as the combined effluent line. The sample container should be clean to avoid bad results. If an automatic system is used, the lines should be flushed regularly to avoid build-up of solids or other deposits.

Sidestreams

There are normally no major sidestreams associated with an activated carbon contact system. However, when the system also acts as a filter, there will be sidestreams associated with the backwashing cycle as described for the filtration process. When the carbon has not been washed well, carbon fines (dust) are present and can be found in the effluent. Carbon fines in the effluent result in erroneous chemical oxygen demand tests as well as greater suspended solids concentrations and higher turbidities. To avoid these problems, activated carbon systems are often provided with the necessary piping to "waste" the first flow through the columns by returning it to the the plant treatment. Such sidestreams are very small and do not add a significant load to the plant.

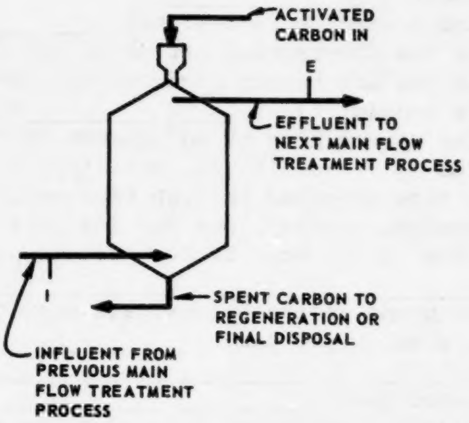
ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

ACTIVATED CARBON ADSORPTION

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
COD	ALL	3/W	I E	24C	H P[1]
pH	ALL	Mn	I	Mn	H P
MBAS	ALL	1/D	I E	24C	P


ACTIVATED CARBON IN
E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
I
SPENT CARBON TO REGENERATION OR FINAL DISPOSAL
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. PROCESS CONTROL ON EFFLUENT
2. PROCESS CONTROL FOR SYSTEM EQUIPMENT FOR pH ADJUSTMENT

Figure 16-2

Process Checklist - Activated Carbon Adsorption

1. What is actual plant flow?_________ mgd avg.
2. What is total flow through the carbon system?__________ mgd.
3. How many contactors? ___________________________
4. What is flow through each contactor _______________ mgd ___________ mgd _________ mgd __________ mgd
5. What type of carbon system? ( ) gravity ( ) pressure ( ) Upflow ( ) downflow ( ) parallel ( ) series ( ) Other ________________
6. What are contactor dimensions? ___________________
7. What is the COD removal per lb of carbon? ___________________________ lbs/lb
8. What is the lbs carbon used per million gallons? ____________________ lbs/MG
9. What is contact time?________________min
10. Does the system have pH adjustment as part of the carbon process? ( ) Yes ( ) No. If yes, what type and dose? _______________________
11. Is the flow measured through each contactor? ( ) Yes ( ) No
12. For pressure systems, are the influent pumps operating properly? ( ) Yes ( ) No. If no, what is problem? ______________________________ ____
13. If have pumps in the system, are they operating? ( ) Yes ( ) No If no, what is problem? ____ What are the pumps used for? ____
14. Do mechanical equipment have adequate spare parts inventory? ( ) Yes ( ) No. If no, what is problem? ____
15. Is the carbon building adequately ventilated? ( ) Yes ( ) No
16. How often are the facilities checked? ( ) once per shift ( ) daily ( ) other ____
17. What is frequency of scheduled maintenace? _______________________________ ____
18. Is the maintenance program adequate?( ) Yes ( ) No. If no, explain ____
19. What is the general condition of the carbon system? ( ) good ( ) fair ( ) poor
20. What are the most common problems the operator has had with the activated carbon system? ____
____
____
____
____
____

References

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2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

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5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

6. State of Virginia O&M inspection form.

7. Culp, Gordon L., and Culp, Russell L., New Concepts in Water Purification, Van Nostrand Reinhold, 1974.

8. Culp, Russell L., Wesner, G. M., and Culp, Gordon L., Handbook of Advanced Wastewater Treatment, Van Nostrand Reinhold, 1978.

9. CH2M-Hill, Process Design Manual for Carbon Adsorption, USEPA, Technology Transfer, April 1976.

10. Shuckrow, A.M. and Culp, G.L., "Appraisal of Powdered Activated Carbon Processes for Municipal Wastewater Treatment," USEPA Report EPA-600/2-77-156, September 1977.

17. NITRIFICATION

Process Description

Nitrification is a biological process in which specific organisms convert ammonia-nitrogen (NH_3-N) to nitrate-nitrogen (NO_3^--N). Nitrification can be accomplished by a two-stage process with separate oxidation of carbonaceous material (BOD) and nitrogen or single-stage schemes in which both BOD and NH_3-N are removed in the same basin. All nitrification systems are sensitive to low temperatures.

Extended aeration activated sludge systems have long aeration times (24 hours) and high solids retention times (20 to 30 days). This process is good for maintaining a large population of nitrifying bacteria in a single treatment unit.

Attached growth biological treatment systems, when properly designed and operated can also produce nitrified effluent. A single-stage trickling filter system designed for a very low organic loading in a warm climate can produce nitrified effluent. Synthetic media has been found more effective than rock media because it provides a greater, more uniform surface area. In two-stage trickling filter systems, the first filter is designed as a roughing filter to remove BOD and the second is designed for nitrification. In this case, the contact time (wetting rate) rather than the organic loading determines process performance. Trickling filters can also be used in a two-stage system following secondary treatment by activated sludge. The influent to the filter must have a low BOD concentration (less than 20 mg/l) to provide effective nitrification.

The ABF system can be designed to provide almost complete nitrification. The tower or bio-cell is designed for BOD removal and the aeration basin for additional BOD removal and complete ammonia conversion.

Rotating biological contactors (RBC's) are an effective means of single or two-stage nitrification. The first series of discs in the system provides BOD removal, while the downstream units provide nitrification.

The reader should refer to Reference 1 and other sections of this manual to obtain more specific process information.

Typical Design Considerations

The basic design procedures for nitrification follow the same steps as for conventional secondary treatment, but the criteria for process sizing and the selection of equipment are different. Table 17-1 summarizes the basic design criteria for suspended growth systems. The oxygen requirement for nitrification is about 4.6 lb O_2/lb NH_3 removed; this amount must be supplied over and above the carbonaceous oxygen demand of about 1.4 lb O_2/lb BOD removed. If the dissolved oxygen (DO) drops below 1 mg/l, nitrification will be reduced. In the activated sludge process, the degree of nitrification depends on the sludge retention time (SRT). Nitrification normally requires an SRT of about 10-12 days.

TABLE 17-1. DESIGN PARAMETERS FOR TYPICAL SUSPENDED GROWTH NITRIFICATION SYSTEMS

Single-Stage Nitrification		
Loading	lb BOD$_5$/1000 cu ft/day	10-30
F/M	lb BOD$_5$/1000 lb MLSS/day	0.05-0.15
SRT	days	10-15
Aeration time	hrs	6-12
Solids recirculation	%Q	30-100
MLSS	mg/l	3000-6000
Extended Aeration		
Loading	lb BOD$_5$/1000 cu ft/day	10-15
F/M	lb BOD$_5$/1000 lb MLSS/day	<0.05
SRT	days	≥ 30
Aeration time	hrs	16-24
Solids recirculation	%Q	100-300
MLSS	mg/l	2000-6000
Two-Stage Nitrification		
Carbonaceous removal by high-rate activated sludge		
Loading	lb BOD$_5$/1000 cu ft/day	70-180
F/M	lb BOD$_5$/lb MLSS/day	0.4-1.0
SRT	days	2-4
Aeration time	hrs	2-4
Solids recirculation	%Q	30-100
MLSS	mg/l	3000-5000
Nitrogen removal by conventional plug-flow, aeration		
Loading	lb NH$_3$-N/1000 cu ft/day	10-20
SRT	days	10-20
Aeration time	hrs	3
Solids recirculation	%Q	30-100
MLSS	mg/l	1000-2000

Nitrification will generally not occur in trickling filters loaded at greater than 12 lb BOD/1000 cu ft/day. For good nitrification to occur the loading should be less than 5 lb BOD/1000 cu ft/day. As indicated previously in Table 17-1, this value is the minimum loading for a low rate filter. Plants which include recirculation generally produce a greater degree of nitrification. Synthetic media trickling filters tend to be more effective for nitrification since they have a greater specific surface area on which nitrifying organism can grow. For two-stage trickling filters, nitrification is limited by the contact time. Typical values for a 21.5-foot deep synthetic media filter are given in Table 17-2.

TABLE 17-2. HYDRAULIC LOADING FOR TWO-STAGE NITRIFYING TRICKLING FILTER

Nitrification performance, %	Wetting Rate, gpm/sq ft 18°C	 7°C
90	0.5	0.50
85	0.75	0.65
80	1.0	0.75
75	1.5	0.85

The design criteria for the biofilter is the same as that for the standard ABF system; it is designed to remove only BOD and not ammonia from the wastewater. Nitrification as well as additional BOD removal occurs in the aeration basin. The design parameters for ABF nitrification are summarized in Table 17-3. The aeration detention time is about four times that for regular oxidation and the organic loading about one-third.

The design relationship for single-stage nitrifying RBC's is given on Figure 17-1. The hydraulic loadings for various influent BOD and ammonia concentrations are presented. When used following secondary treatment, RBC's should be designed according to the relationship given on Figure 17-2. The basic curves are for a four-stage system achieving 90 to 95 percent nitrification.

Typical Performance Evaluation

Virtually any level of nitrification can be achieved with any of the processes described herein if the design parameters are selected according to the treatment conditions. The most common cause of systems not meeting design standards are cold weather and peak flows. These factors should be considered when evaluating processes.

TABLE 17-3. GENERAL DESIGN PARAMETERS FOR NITRIFICATION OF DOMESTIC WASTEWATER WITH ABF PROCESS

Parameter	Units	Typical value	Range
Effluent criteria			
5-day BOD	mg/l	15	5-30
Suspended solids	mg/l	20	15-30
NH_3-N	mg/l	1.0	0.5-2.5
Bio-cell parameters			
Organic load	lb BOD_5/day/1000 cu ft	200	100-350
Media depth	ft	14	5-22
BOD_5 removal	%	65	55-85
Hydraulic parameters			
Bio-cell recycle	*	1.5 Q	0.5-2.0 Q
Sludge recycle	*	0.5 Q	0.3-1.0 Q
Bio-cell flow	*	3.0 Q	2.3-4.0 Q
Bio-cell hydraulic load	gpm/sq ft	3.5	1.5-5.5
Aeration parameters**			
Detention time*	hr	3.5	2.5-5.0
Organic load	lb BOD_5/day/1000 cu ft	25	20-40
Ammonia load	lb NH_3-N/day/1000 cu ft	10	5.0-15.0
F/M	lb BOD_5/day/lb MLVSS	0.13	0.1-0.2
MLVSS concentration	mg/l	3000	1500-4000
MLSS concentration	mg/l	4000	2000-5000
Carbonaceous oxygen***	lb O_2/lb BOD_5	1.4	1.2-1.5
Sludge production	lb VS/lb BOD_5 removed	0.45	0.30-0.55

* Based on design average flow and secondary influent BOD_5 = 150 mg/l.

** Based on aeration BOD_5 loading after bio-cell removal.

*** Total oxygen utilization = carbonaceous oxygen + 4.6 lb O_2/lb NH_3-N oxidized.

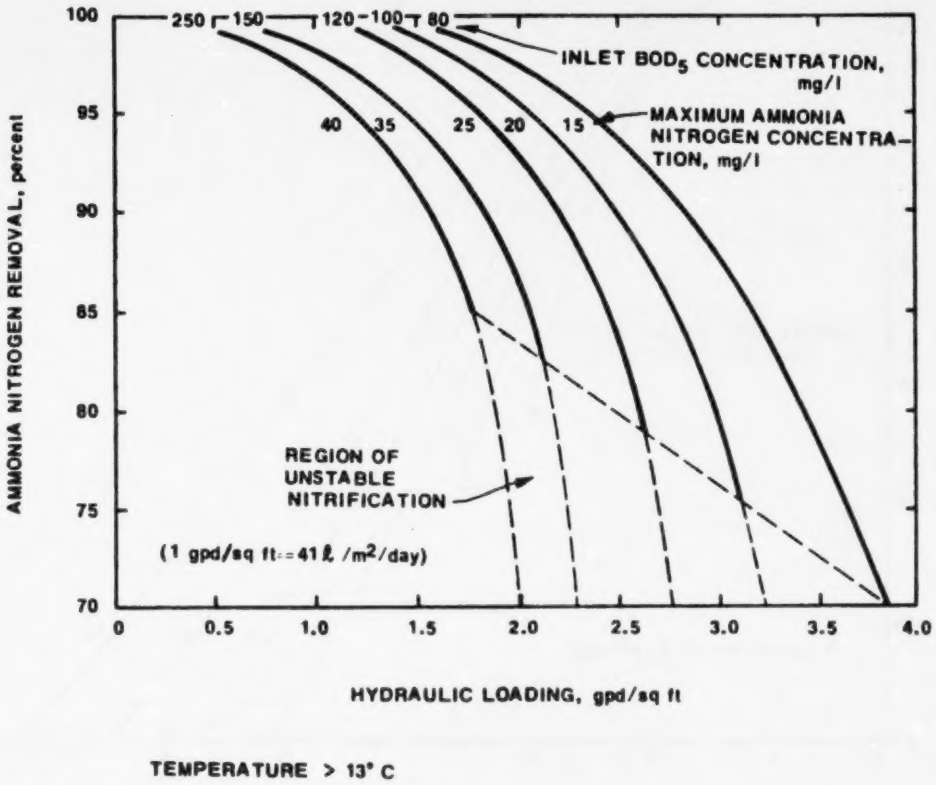
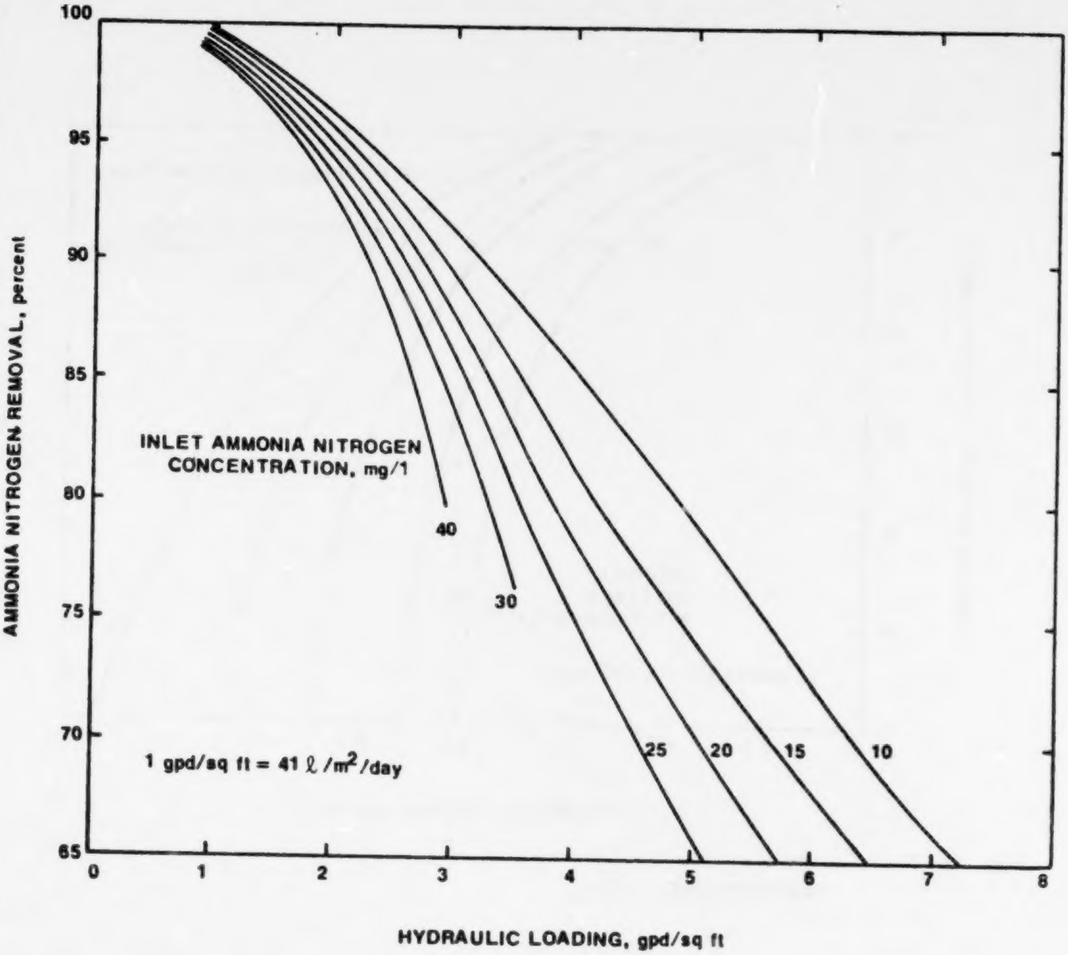


Figure 17-1. Effect of BOD$_5$ concentration and hydraulic load on nitrification in the RBC process.



RELATIVE CAPACITIES
FOR STAGED OPERATION
(90–95% Nitrification)

No. Stages	Relative Capacity
1	0.60
2	0.80
3	0.90
4	1.00
6	1.07

Conditions

Temperature > 13°C
$BOD_5 < 20$ mg/l

Figure 17-2. Design relationships for a 4-stage RBC process treating secondary effluent.

Process Control

Because nitrifying bacteria are slow-growing and sensitive to environmental conditions, close process monitoring and specific control features must be followed. Loss of nitrifying bacteria can mean inadequate treatment for many months while they re-establish themselves. There are several key factors influencing the nitrification process.

The concentration of dissolved oxygen (DO) has a significant effect on the rate of nitrification in biological wastewater treatment systems. Although nitrification can be achieved at DO levels of 0.5 mg/l, it is at a very low rate. The DO of the wastewater should be kept at 1 to 3 mg/l for consistent nitrification. Air can be supplied by additional aeration of suspended growth systems and by increased ventilation of attached growth units.

Certain heavy metals, complex anions, and organic compounds which are toxic to nitrifiers are listed in Table 17-4. The amounts of these substances necessary to effect nitrifiers depend on the overall environment of a particular system. A good source control program should be established to prevent harmful concentrations of toxic materials from entering the treatment stream.

TABLE 17-4. SUBSTANCES TOXIC TO NITRIFYING ORGANISMS

Organics	Inorganics
Thiourea	Zn
Allyl-thiourea	OCN^{-1}
8-hydroxyquinoline	ClO^{-1}
Salicyladoxine	Cu
Histidine	Hg
Amino acids	Cr
Mercaptobenzthiazole	Ni
Perchloroethylene	Ag
Trichloroethylene	
Abietec acid	

Maintenance Considerations

Maintenance considerations for the specific facility used apply here also.

Records

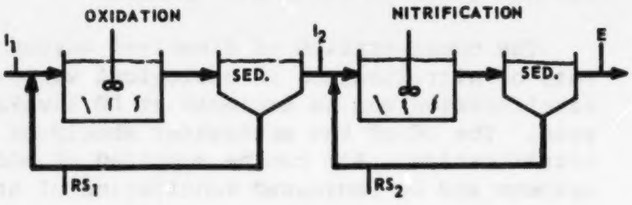
Recommended sampling and laboratory tests are shown in Figure 17-3 through 17-6, depending on the basic process being examined.

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	P
	SUSPENDED SOLIDS	ALL	5/W	E	24C	P
	SETTLEABILITY	ALL	5/W	E	G	P
	pH	ALL	5/W	P	G	P
	DO	ALL	5/W	P	G	P
	AIR INPUT[1]	ALL	R	B	R	H
	NH_3-N	ALL	1/D	I[2] E	24C	P
	ORG-N	ALL	1/D	I[2] E	24C	H
	NO_3-N	ALL	1/D	I[2] E	24C	H
	FLOW	ALL	R	RS	R	P
OPTIONAL	MICROSOPIC ANALYSIS	ALL	2/W	P	G	H
	TOTAL SOLIDS	>1	3/W	E	24C	H
	TOTAL VOLATILE SOLIDS	>1	3/W	E	24C	H
	COD	>5	2/W	I	24C	H

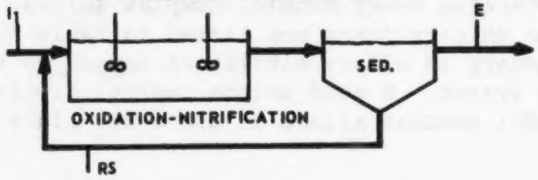
ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

NITRIFICATION

2 – STAGE ACTIVATED SLUDGE



1 – STAGE ACTIVATED SLUDGE



I_1 = INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
I_2 = EFFLUENT FROM 1ST STAGE
E = EFFLUENT TO DOWNSTREAM PROCESS
RS= RECYCLE SLUDGE

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn= MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
RS= RECYCLE SLUDGE
B = BLOWER

C. METHOD OF SAMPLE

24C= 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

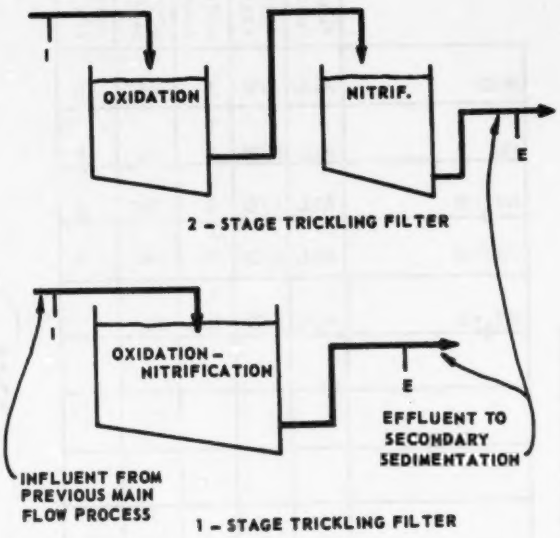
1. DIFFUSED AIR ONLY
2. MAYBE RUN ON PLANT INFLUENT IF THIS IS INITIAL UNIT PROCESS FOLLOWING PRETREATMENT

Figure 17-3

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

NITRIFICATION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	P
	NH_3-N	ALL	1/D	I E	24C	P
	ORG-N	ALL	1/D	I E	24C	H
	NO_3-N	ALL	1/D	I E	24C	H
	DO	ALL	5/W	I E	G	P
OPTIONAL	COD	>5	2/W	I	24C	H


I
OXIDATION
NITRIF.
E
2 - STAGE TRICKLING FILTER
I
OXIDATION - NITRIFICATION
E
EFFLUENT TO SECONDARY SEDIMENTATION
INFLUENT FROM PREVIOUS MAIN FLOW PROCESS
1 - STAGE TRICKLING FILTER

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

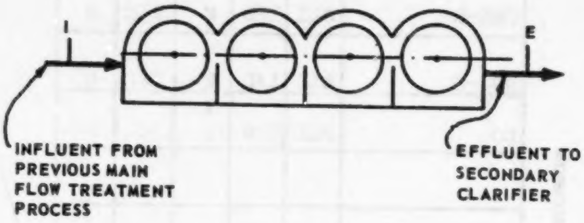
Figure 17-4

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

NITRIFICATION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	H
	DO	ALL	5/W	I E	G	H
	NH_3-N	ALL	1/D	I E	24C	P
	ORG-N	ALL	1/D	I E	24C	H
	NO_3-N	ALL	1/D	I E	24C	H
OPTIONAL	COD	>5	2/W	I	24C	H

ROTATING BIOLOGICAL CONTACTOR


I
E
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
EFFLUENT TO SECONDARY CLARIFIER

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

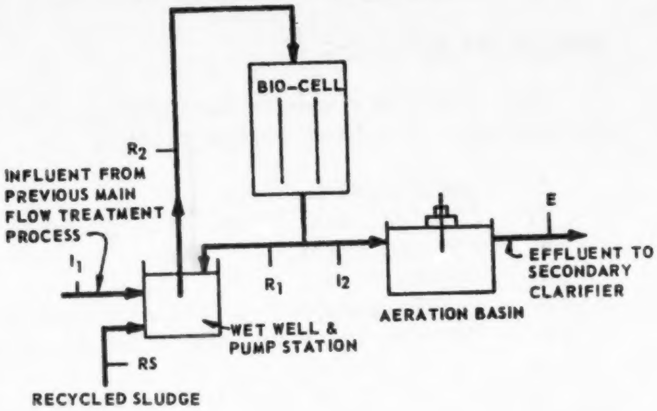
1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 17-5

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

NITRIFICATION

ACTIVATED BIOFILTER PROCESS



BIO-CELL
R_2
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
I_1
R_1
I_2
E
EFFLUENT TO SECONDARY CLARIFIER
AERATION BASIN
WET WELL & PUMP STATION
RS
RECYCLED SLUDGE

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I_1 I_2	24C	P
	SUSPENDED SOLIDS	ALL	5/W	E_2	24C	P
	SETTLEABILITY	ALL	5/W	E_2	G	P
	pH	ALL	5/W	I_2 E	G	P
	DO	ALL	5/W	I_2 E	G	P
	FLOW	ALL	R	I, R_1 R_2, RS	R	P
	NH_3-N	ALL	1/D	I_2 E	24C	P
	ORG-N	ALL	1/D	I_1 E	24C	H
OPTIONAL	COD	>5	2/W	I_1 E	24C	H
	TOTAL SOLIDS	>1	3/W	E	24C	H
	TOTAL VOLATILE SOLIDS	>1	3/W	E	24C	H
	MICROSCOPIC ANALYSES	ALL	2/W	R_1 E	G	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I_1 = INFLUENT TO WETWELL
I_2 = INFLUENT TO AERATION BASIN
E = EFFLUENT FROM AERATION BASIN
RS = RECYCLED SLUDGE
R_1 = BIO-CELL RECYCLE R_2 = BIO-CELL RECIRCULATION

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 17-6

Other operating records should include:

1. Raw sewage influent flow.
2. Total electrical energy consumed.
3. Recirculation flows - liquid and solids.
4. MLSS and MLVSS in any aeration basins and return sludge lines.
5. The unit volume of air supplied per lb BOD and ammonia removed by any aeration equipment.
6. Quantity and location of lime or caustic added to buffer wastewater.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the activated sludge process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Oxygen analyzer or titration equipment
6. Wet chemistry equipment for monitoring ammonia conversion

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected at points in the process where the wastewater is well mixed and homogeneous. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The sidestreams associated with nitrification are the same as those associated with carbonaceous oxidation. There is little wasting of solids from the nitrification step of two-stage processes and reduced wasting from single-stage process. Refer to the secondary sedimentation section for additional information on sidestreams.

Process Checklist - Suspended Growth Nitrification

1. What is the actual plant flow? ______________mgd, average; ________________ mgd, peak.
2. How many stages does the nitrification system have? ______________. What type of aeration system (flow regime) does each have? ____________________
   ____
3. What type of aeration equipment does each have? ____________________
   ____
   Number of units ________________ Capacity of each unit ______________
4. What are the aeration basin(s) dimensions?______________________________
   ____
5. Basin characteristics - Carbonaceous oxidation: Color ( ) Black
   ( ) Dark Brown ( ) Light Brown ( ) Other ____________________
   Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ______________
   Foam ( ) Light, crisp ( ) Dark, thick ( ) heavy white
   ( ) Other ______________________________
6. Basin characteristics - Nitrification: Color ( ) Black
   ( ) Dark Brown ( ) Light Brown ( ) Other ____________________
   Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ______________
   Foam ( ) Light, crisp ( ) Dark, thick ( ) heavy white
   ( ) Other ______________________________
7. Are tank(s) contents mixed thoroughly? ( ) Yes ( ) No
8. Are all diffusers or mech. aerators operating properly? ( ) Yes ( )No
9. Does mixing appear excessive? ( ) Yes ( ) No
10. Do there appear to be dead spots in tank(s) ( ) Yes ( ) No
    If yes, at what location? ____
11. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ____
12. Are RAS pumps operating? ( ) Yes ( ) No. If no, what is the reason? ____
13. Are there flow measurement devices for the RAS and WAS systems
    ( ) Yes ( ) No. Are they operable? ( ) Yes ( ) No
14. Does the aeration basin(s) have a foam control system? ( ) Yes ( ) No
    Is it operable? ( ) Yes ( ) No. Is it operating? ( ) Yes ( ) No
15. If multiple basins for each step are operating, is the flow distributed equally? ( ) Yes ( ) No How is it distributed ________________
16. Are the characteristics of the basin contents for each step different?
    ( ) Yes ( ) No. If yes, describe ______________________________
    ____
17. Is there an alkaline buffer added? ( ) Yes ( ) No. If yes, what is it? ____________________. Dose ____________________.
18. Is operation of the system ( ) Manual ( ) Semi-Automatic
    ( ) Automatic ( ) Computer controlled ( ) Other ______________
19. Is there an adequate spare parts inventory? ( ) Yes( ) No. What does it contain? ____
20. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
21. How often are facilities checked? ( ) Once per shift ( ) Daily
    ( ) Other __________________
22. What is frequency of scheduled maintenance?________________________
    ____

23. Is the maintenance program adequate? ( ) Yes ( ) No
If no, explain ______________________________

24. What is general condition of the nitrification facilities?
( ) good ( ) fair ( ) poor

25. What are the most common problems the operator has had with the nitrification system? ______________________________
____
____
____
____

Process Checklist - Nitrifying Trickling Filters

1. What is actual plant flow?________ mgd, average; ________mgd, peak
2. How many stages? ______________________.
3. What is recycle flow to each stage? Is it ____________ constant, __________ intermittent?
4. What type of media is used?______________________________
5. What is the depth of media?______________ feet
6. Number of units in each stage _____________; Size of units ____________. ______________________________.
7. Characteristics of Oxidation Tower:
Color ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
Odor ( ) Septic ( ) Earthy ( ) None ( ) Other _______________.
8. Characteristics of Nitrification Tower:
Color ( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
Odor ( ) Septic ( ) Earthy ( ) None ( ) Other _______________.
9. Is there evidence of uneven flow distribution in each stage? ( ) Yes ( ) No. Are any nozzles clogged? ( ) Yes ( ) No
10. Is there evidence of filter clogging such as ponding? ( ) Yes ( ) No. Icing? ( ) Yes ( ) No Other ____________________.
11. Is there evidence of filter flies? ( ) Yes ( ) No. Snails ( ) Yes ( ) No. Roaches ( ) Yes ( ) No. Other ______________
12. Is there grass or other vegetative material growing on the filter? ( ) Yes ( ) No Other ______________________.
13. Are there flow measurement devices for the recirculation flow? ( ) Yes ( ) No. Are they operable? ( ) Yes ( ) No
14. Are the recirculation pumps operating? ( ) Yes ( ) No. If no, why? ______________________________
____
15. If multiple filters are operating for each stage, is the flow distributed equally?( ) Yes ( ) No How is it distributed? ______________
16. Are the characteristics of the filter contents different in the various units of each stage? ( ) Yes ( ) No. If yes, describe ____________
______________________________.
17. Is operation of the system ( ) manual ( ) semi-automatic ( ) automatic ( ) computer controlled ( ) other ________________
18. Is there an alkaline buffer added? ( ) Yes ( ) No. If yes, what is it? ______________________________. Dose ____________________.

19. Does mechanical equipment (flow distributors, pumps, etc) have adequate spare parts inventory? ( ) Yes ( ) No. What does it contain?
____.
20. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
21. How often are facilities checked? ( ) Once per shift ( ) Daily
( ) other __________________________.
22. What is frequency of scheduled maintenance?______________________________
____.
23. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ______________________________________.
24. What is general condition of the nitrification facilities?
( ) good ( ) fair ( ) poor
25. What are the most common problems the operator has had with the nitrification system? ______________________________
____
____
____
____

Process Checklist - Nitrifying Rotating Biological Contactors

1. What is actual plant flow?____________ mgd, average;__________ mgd peak?
2. Number of stages ____________________________.
3. Type of RBC media ____________________________
3. Type of RBC drive__________________________; Number of shafts _____;
and surface area of each unit ___________________
4. Color of biomass ( ) Black ( ) Dark Brown ( ) Light Brown
( ) Other _________________________.
5. Odor ( ) Septic ( ) Earthy ( ) None ( ) Other ___________.
6. Are all drives operating properly? ( ) Yes ( ) No. What type of drive is used ( ) Mech. ( ) Air?
7. Is rotation of media uniform? ( ) Yes ( ) No
8. Is the flow distributed equally to parallel shafts? ( ) Yes ( ) No
How is it distributed? ______________________________
9. Are the characteristics of the tank contents different in the various units? ( ) Yes ( ) No. If yes, describe ______________
____
10. Is there an alkaline buffer added? ( ) Yes ( ) No. If yes, what is it? ______________________. Dose ____________.
11. Does mechanical equipment (mechanical drives, motors, etc.) have an adequate spare parts inventory? ( ) Yes ( ) No. What does it contain? ____
Are the units housed in a building? ( ) Yes ( ) No, or does each unit have a cover? ( ) Yes ( ) No
12. Is the RBC housing adequately ventilated? ( ) Yes ( ) No.
13. How often are facilities checked? ( ) once per shift ( ) daily
( ) other _______________.
14. What is frequency of scheduled maintenance?______________________________
____

15. Is the maintenance program adequate? ( ) Yes ( ) No
If no, explain ____________________

16. What is general condition of the nitrification facilities?
( ) good ( ) fair( ) poor

17. What are the most common problems the operator has had with the nitrification system? ____________________
____
____
____
____

Process Checklist - Nitrifying ABF

1. What is actual plant flow?________ mgd, average; __________mgd, peak
2. What is underflow recycle rate ____________mgd? What is the solids recycle rate to the bio-cell ______________mgd?
3. What type of media is used in the biocell?____________________
4. What is the depth of media ______________ feet?
5. Number of bio-cell units ____________; Size of bio-cell units __________
6. Type of aeration system (flow regime) ____________________
7. Type of aeration equipment ________________; Number of units ________
Capacity of each unit __________________; Tank dimensions __________
8. Color of bio-cell growth:
( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
Color of activated sludge:
( ) Black ( ) Dark Brown ( ) Light Brown ( ) Other__________
9. Odor of bio-cell growth:
( ) Septic ( ) Earthy ( ) None ( ) Other ______________
Odor of activated sludge:
( ) Septic ( ) Earthy ( ) None ( ) Other ______________
10. Is there evidence of uneven flow distribution? ( ) Yes ( ) No. Are any nozzles clogged? ( ) Yes ( ) No
11. Is there evidence of filter clogging, such as ponding? ( ) Yes ( ) No
12. Is there evidence of filter flies? ( ) Yes ( ) No. Snails? ( ) Yes ( ) No. Roaches? ( ) Yes ( ) No. Other ______________
13. Is there grass or other vegetative material growing on filter? ( ) Yes ( ) No. Other ____________________
14. Are there flow measurement devices for the recirculation and return sludge flows? ( ) Yes ( ) No. Are they operable? ( ) Yes ( ) No
15. Are recirculation left station and RAS pumps operating? ( ) Yes ( ) No. If no, what is the reason? ____________________
16. If multiple bio-cells are operating, is the flow distributed equally? ( ) Yes ( ) No How is it distributed?______________
17. Are the characteristics of the bio-cells contents for each step different? ( ) Yes ( ) No. If yes, describe ____________________
____
18. Are aeration tank contents mixed thoroughly? ( ) Yes ( ) No
19. Are aerators operating properly? ( ) Yes ( )No
20. Does mixing appear excessive? ( ) Yes ( ) No

21. Do there appear to be dead spots in the aeration tank? ( ) Yes ( ) No If yes, at what location? ____________________

22. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ____________________

23. Does the aeration basin have a foam control system?( ) Yes ( ) No Is it operable? ( ) Yes ( ) No. Is it operating? ( ) Yes ( ) No

24. If multiple basins for each step are operating, is the flow distributed equally? ( ) Yes ( ) No How is it distributed ____________

25. Is there an alkaline buffer added? ( ) Yes ( ) No. If yes, what is it? ____________. Dose ____________.

26. Is operation of the system ( ) Manual ( ) Semi-Automatic ( ) Automatic ( ) Computer controlled ( ) Other ____________

27. Does mechanical equipment (flow distributors, pumps, mechanical aerators, etc) have adequate spare parts inventory? ( ) Yes ( ) No

28. Is the pump station housing adequately ventilated? ( ) Yes ( ) No

29. How often are facilities checked? ( ) Once per shift ( ) Daily ( ) Other ____________

30. What is frequency of scheduled maintenance? ____________________
____

31. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ____________________

32. What is general condition of the nitrification facilities? ( ) good ( ) fair ( ) poor

33. What are the most common problems the operator has had with the nitrification system? ____________________
____
____
____
____

References

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11. Dunnahoe, R.G., and Hemphill, B.W., "The ABF Process, A Combined Fixed/Suspended Growth Biological Treatment System", AWWA-FACE Conference (September 1976).

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18. DENITRIFICATION

Process Description

Denitrification is the reaction in which nitrate-nitrogen gas (NO_3-N) is converted to nitrogen gas (N_2). It occurs when nitrified wastewater comes in contact with certain microorganisms and there is no oxygen present. If low effluent nitrogen is desirable, controlled denitrification is one way to meet treatment standards. Unaided denitrification is a slow process, however, it can be speeded up if an oxygen-demanding food source is added to the wastewater. Methanol is commonly used. Industrial waste which is low in nitrogen, such as that from a brewery, can also be used.

Suspended growth denitrification requires a gently mixed, plug-flow reactor followed by solids separation. Although a tightly fitting cover may not be needed, the dissolved oxygen of the wastewater must be kept below 0.5 mg/l. Mixing is provided to keep solids in suspension without adding oxygen to the reactor. In order to release the nitrogen gas and carbon dioxide produced in the denitrification reaction, short-term aeration must be provided before final sedimentation. This also oxidizes any methanol which might remain in the wastewater after denitrification.

The alternative to suspended growth denitrification is an attached growth system. Many types of media have been tested and used including plastic, sand and activated carbon. In general, re-aeration is not required following fixed growth denitrification, but final sedimentation or filtration is needed to remove solids from the effluent. Depending on the mode of operation of the denitrification system, backwashing may be required.

Typical Design Considerations

Suspended growth reactors are usually designed as plug-flow units to prevent short circuiting. Submerged mechanical mixers (0.25-0.5 hp/1000 cu ft) are usually used for mixing. Detention times range from 1 to 3 hours, depending upon temperature conditions (longer detention times at lower temperatures) and nitrogen concentrations. The mixed liquor volatile suspended solids should be maintained at least 1500 to 2000 mg/l and the sludge recycle capacity should be 50 to 100 percent of average flow.

About 3 mg/l of methanol usually is fed per mg/l of nitrate-nitrogen. Other organic materials also have been used, but cause increased sludge production. For example, about twice as much sludge is produced when saccharose is used instead of methanol. Low-nitrogen industrial wastes (such as brewery wastes) have also been used when available. Automatic methanol feed systems are recommended since the organic source must be carefully controlled.

Post-denitrification aeration should only be long enough for facultative bacteria to be mixed with the waste flow. While they oxidize the residual methanol, the mixing action releases the nitrogen gas and carbon dioxide trapped in the biological flocs. This can generally be accomplished in less than one hour.

The design of denitrification columns depends on the configuration and media used. Examples of process sizing include using 6 feet of uniformly graded 2- to 4- mm sand. Filtration rates of 1.0 and 2.5 gpm/sq ft at 10°C and 21°C, respectively, have removed 20 mg/l NO_3-N from wastewater. Mixed-media filters (coal, sand, garnet) have also been used as downflow, packed beds for denitrification. Using a 36-inch mixed-media filter (3 inches of 0.27 mm garnet, 9 inches of 0.5 mm sand, 8 inches of 1.05 mm coal, and 16 inches of 1.75 mm coal), almost complete denitrification is possible at 1.5 gpm/sq ft at a temperature of 10°C, and at 3 gpm/sq ft at a temperature of 20°C.

Typical Performance Evaluation

The overall effectiveness of nitrogen reduction by nitrification-denitrification depends on the nitrification process. Since denitrification is only effective in reducing NO_3-N, a high level of nitrification is important. A good system can produce an effluent with a total nitrogen concentration of about 2 to 3 mg/l. About half of this would be organic-N and the remainder ammonia and nitrate-N. Data from actual operating plants is lacking since there are no established, full-scale operations. Pilot-scale test data indicate that about 90 percent nitrogen removal can be achieved on a long-term basis.

The following example illustrates the evaluation of typical denitrification process performance.

1. Determine process characteristics
   Suspended growth denitrification
   Design flow, average = 10 mgd
   , peak = 15 mgd
   NO_3-N concentration
   Influent = 20 mg/l
   Effluent = 1.5 mg/l
   MLVSS = 2000 mg/l
   Minimum temperature = 10°C
   Denitrification volume = 120,000 cu ft
2. Determine process loading
   Total peak NO_3-N loading = Influent NO_3-N concentration (mg/l) x peak flow (mgd) x 8.34 lb/mg/l
   = 20 x 15 x 8.34 = 2500 lb/day

   $$\text{Denitrification tank loading} = \frac{\text{Total peak } NO_3\text{-N loading (lb/day)}}{\text{Tank volume (cu ft)} - 1000}$$

   $$= \frac{2500 \times 1000}{120{,}000} = 21 \text{ lb } NO_3/1000 \text{ cu ft/day}$$
3. Determine efficiency of nitrate removal for the system.

   $$\%\ NO_3\text{-N removal} = \frac{(\text{Influent } NO_3\text{-N} - \text{Effluent } NO_3\text{-N}) \times 100}{\text{Influent } NO_3\text{-N}}$$

   $$= \frac{20 - 1.5}{20} \times 100 = 93\%$$

Process Control

As with nitrification, pH and temperature will affect the rate of denitrification. Denitrification rates are much lower when the pH is below 6.0 or above 8.0. The highest rates occur around 7.0. The denitrification reaction produces bicarbonate while reducing carbonic acid. This tends to neutralize any acid produced during nitrification and reduces or eliminates the need for chemical addition to adjust the pH of the wastewater.

Temperature has a significant affect on the rate of denitrification. There is a marked suppression of denitrification below 15°C. To compensate for lack of denitrification in extremely cold climates, covered units can be used.

The methanol feed rate is one of the few process controls available. Generally, methanol feed is automatically paced according to the nitrate concentration in the nitrified effluent. If for any reason there is a process upset, methanol can be fed manually. However, excess methanol can result in high effluent BOD and possible discharge violations.

Fixed bed reactors must be backwashed periodically to prevent media clogging and increases in headloss. To prevent excessive accumulation of nitrogen gas in the columns, a "bumping" procedure should be used after four to twelve hours of operation. It consists of a short backwash cycle lasting one or two minutes. When several filters are used, backwashed filter effluents are blended with those from operating filters in order to reduce the effects of any initial nitrate leakage.

Maintenance Considerations

The features of a good maintenance program are listed below. These should be combined with sedimentation and general maintenance management.

1. Spare parts inventory should contain at least the following parts: one set of each type of bearing, V-belt or chain drives for each system, grease seals, all necessary gasket for replacement of parts, one set each of mechanical seals, washers or sheaves to allow for adjustment of impellers.

2. Inspection each shift of the denitrification basin or fixed growth column appurtenant facilities to visibly inspect the equipment.

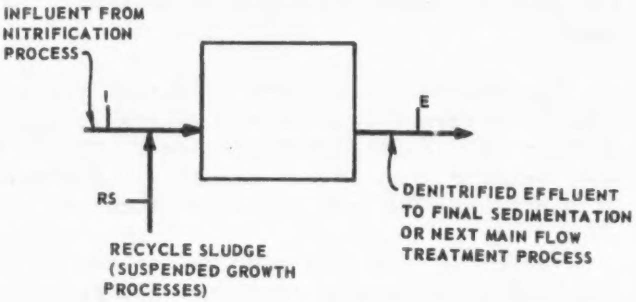
Records

Recommended sampling and laboratory tests are shown in Figure 18-1.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

DENITRIFICATION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	pH	ALL	5/W	I	G	H
	DO	ALL	5/W	I	G	P
	NH_3-N	ALL	1/D	I	24C	P
	ORG-N	ALL	1/D	I	24C	H
	NO_3-N	ALL	1/D	I E	24C	P
OPTIONAL						


INFLUENT FROM NITRIFICATION PROCESS
I
E
RS
RECYCLE SLUDGE (SUSPENDED GROWTH PROCESSES)
DENITRIFIED EFFLUENT TO FINAL SEDIMENTATION OR NEXT MAIN FLOW TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. THIS PROCESS MUST FOLLOW BIOLOGICAL NITRIFICATION

Figure 18-1

Other operating records should include:

1. Raw sewage influent flow.
2. Return sludge flows for suspended growth systems.
3. MLSS and MLVSS in the suspended growth basin and the return sludge line.
4. Hydraulic loading and backwash rate on fixed film columns.
5. The total energy (electricity) consumed.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the denitrification process.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. Wet chemistry equipment for monitoring ammonia
4. Spectrophotometer

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected at points where the wastewater is well mixed and homogeneous such as in the denitrification basin close to the mixing device or from the sludge lines after the sludge has been flowing for about a minute. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, sampler tubes should be kept clean.

Sidestreams

There are no significant sidestreams associated with the denitrification processes. Settled solids not recycled within the process are generally diverted to the primary treatment process. The sludge quantity has been found to be about 0.2 lb/lb of methanol feed.

Process Checklist - Denitrification

1. What is actual plant flow __________ mgd avg. __________ mgd peak?
2. Type of denitrification system ______________________________
3. Type of mixing equipment or media ____________________ Number of units ______ and capacity of each unit ______________
4. What are the tank (or column) dimensions? ______________________
5. Are tank contents mixed thoroughly? ( ) Yes ( ) No
6. Are all mechanical mixers operating properly? ( ) Yes ( )No
7. Does mixing appear excessive so as to cause oxygenation? ( ) Yes ( ) No
8. Do there appear to be dead spots in tank? ( ) Yes ( ) No If yes, at what location? ______________________________
9. Is the process operating in its design mode? ( ) Yes ( ) No If no, explain ______________________________
10. Are the column pumping systems operating? ( ) Yes ( ) No.
11. Is the backwash system operating correctly? ( ) Yes ( ) No. How often is it used? __________________________
12. Is operation of the system? ( ) Manual ( ) Semi-Automatic ( ) Automatic ( ) Computer controlled ( ) Other ______________
13. Is there an adequate spare parts inventory? ( ) Yes ( ) No What does it contain? ______________________________ ______________________________
14. Is the pump station housing adequately ventilated? ( ) Yes ( ) No
15. How often are facilities checked? ( ) Once per shift ( ) Daily ( ) Other ______________
16. What is frequency of scheduled maintenance? ______________________________ ______________________________
17. Is the maintenance program adequate? ( ) Yes ( ) No If no, explain ______________________________
18. What is general condition of the denitrification facilities? ( ) good ( ) fair ( ) poor
20. What are the most common problems the operator has had with the system? ______________________________ ______________________________ ______________________________ ______________________________

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

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6. State of Virginia O&M inspection form.

7. Parker, D.S., et al, Process Design Manual for Nitrogen Control, EPA, Technology Transfer, (October 1975).

8. Battelle Pacific Northwest Laboratories, Evaluation of Municipal Sewage Treatment Alternatives, Council on Environmental Quality, Contract EQC316 (February, 1974).

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19. AMMONIA STRIPPING

Process Description

Ammonia stripping is used to remove ammonia from water by passing high volumes of air through an agitated water-gas mixture. In wastewaters, most of the nitrogen is present in the form of ammonium ions (NH_4^+) and must be converted to ammonia gas (NH_3) by raising the pH of the wastewater to the range of 10.8 to 11.5. At this high pH, the nitrogen is almost totally converted to the ammonia form from the ammonium form. Wastewater is pumped to the top of a stripping tower and allowed to fall downwards through a series of splash bars. At the same time, high volumes of air are forced upwards through the stripping tower by a large fan. Lime is almost always used to raise the pH since it also removes phosphorous and suspended solids.

The two types of ammonia stripping towers that are commonly used look much like cooling towers. The towers differ in design only in the location of the air inlet louvers. For the cross-flow tower, the air is drawn through the sides for the total height of the packing. The counter-current tower draws the entire air flow through the bottom of the tower. The cross-flow towers have been found to be more susceptible to scaling problems (build-up of calcium deposits) and are less efficient than the counter-current towers.

Typical Design Considerations

The major design considerations for ammonia stripping towers are pH, temperature, hydraulic loading, tower packing, air flow and scale deposit control.

The pH of the water has a major effect on the efficiency of the process. If the pH is not raised to a value at which all the ammonium ions are converted to ammonia gas, ammonia removal is not complete.

As air and water temperatures decrease, it it harder to strip the ammonia from the water. To maintain ammonia removal efficiencies at lower temperatures, the air volume must be substantially increased.

The hydraulic loading rate is expressed in terms of gallons per minute applied to each square foot of the plan area of the tower packing. The area is selected to allow the formation of water droplets which are needed for efficient ammonia removal. If the loading rate is too high, the efficiency is reduced because the water does not form the droplets. The normal range of loading rate is 1 to 3 gpm/ft^2, but mostly the rates are less than 2 gpm/ft^2.

The tower packing depth, material, and shape all affect the ammonia removal efficiency. The greater the depth the better the performance, up to a maximum of about 24 feet. The packing material can be either wood or plastic, with the plastic showing more resistance to scaling. The shape refers to the shape of the individual members as well as how the members are placed in the tower. Packing should be shaped to produce as many water droplets as possible as the water cascades down through the tower.

Gas transfer relationships and practice show that the percentage ammonia removal is increased with increasing air flow, for a given tower height. There is a practical limit on the air flow rate which is related to the pressure drop across the tower packing. This maximum value is approximately 550 cfm/sq ft. Typical air requirements are about 300 cfm/gal for 90 percent removal and 500 cfm/gal for 95 percent removal.

The scaling, or deposition of calcium carbonate, on the packing material reduces the efficiency of the ammonia removal process. The deposits are caused by the unstable, high pH waters flowing through the tower. To minimize scaling, as much calcium carbonate as possible should be removed during the chemical treatment step. Scaling can also be controlled by eliminating carbon dioxide from the air.

Typical Performance Evaluation

The ammonia stripping process performance is judged on meeting discharge standards. The following steps can be used to check the performance of the stripping process.

1. Obtain the tower dimensions and operating conditions and results.
   Wastewater flow to tower = 5200 gpm
   pH of wastewater = 10.9
   Ammonia concentration in influent and effluent of wastewater = 20 and 2 mg/l, respectively.
   Air temperature = 65°F

2. Check influent pH - it should be above 10.8

3. Check the tower hydraulic loading rate:
   Area covered by tower packing = 4752 sq ft
   Flow to tower = 5200 gpm
   Hydraulic loading = $\frac{5200\text{ gpm}}{4752\text{ sq ft}}$ = 1.1 gpm/sq ft
   Loadings should be less than 2 gpm/sq ft to keep water from moving through the tower in sheets rather than in drops.

4. Check the tower packing to make sure it is not coated with calcium carbonate.

5. Calculate the removal of ammonia in the tower and check the air temperature:
   Influent = 20 mg/l
   Effluent = 2 mg/l
   Removal = $\frac{(20 - 2)}{20} \times 100 = 90\%$
   Air Temperature = 65°F

At 65°F, 90 percent removal is good. For every °F decrease in temperature, the efficiency will drop about 0.5%.

Process Control

The control options for an ammonia stripping facility are related to the influent pH, the rate of air flow, and the hydraulic loading rate. These items are discussed in Reference 1.

Maintenance Considerations

Proper maintenance of a facility will ensure an efficient and trouble free operating plant. The features of a maintenance program to insure these conditions are listed below. They do not consider any other process, such as pH adjustment, which are discussed under other process descriptions.

1. Spare parts inventory should include at least one set of each type of bearing, grease and water seals, all necessary gaskets for replacement of parts, tower packing and spray nozzles.
2. Tower and appurtenant equipment painted regularly to protect against corrosion or weathering.
3. Scale (calcium carbonate) formation regularly cleaned off.
4. Visual examination of the stripping process each shift to check the equipment for misalignment, excessive noise, unequal hydraulic loading or damage to the tower.
5. All wastewater sampling lines flushed out regularly to insure no deposits are formed.

Records

The recommended sampling and laboratory tests are shown in Figure 19-1 for the ammonia stripping process.

Other operating records should include the following:

1. Influent flow rate
2. Air flow rate

Laboratory Equipment

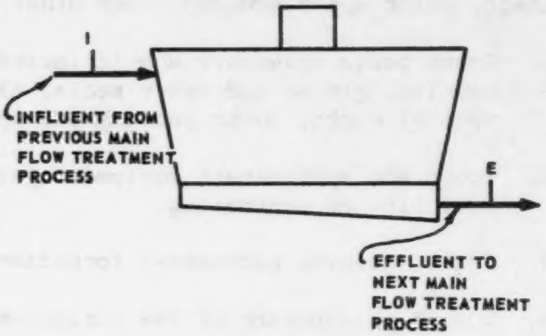
The laboratory should include the following list of equipment as a minimum in order to monitor the ammonia stripping process.

1. pH meter
2. Spectophotometer or filter photometer
3. Nessler Tubes

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

NITROGEN REMOVAL

AMMONIA STRIPPING


I
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
ORG-N	ALL	1/W	I E	24C	H
NO_3-N	ALL	1/W	I E	24C	H
NH_3-N	ALL	1/W	I E	24C	H
pH	ALL	3/D	I E	G	P^1 H
TEMP	ALL	3/D	I E	G	H
HARDNESS	ALL	1/W	I E	24C	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. PROCESS CONTROL ON EFFLUENT

Figure 19-1

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected from the chemical clarifier effluent channel or the influent pumping station wet well and the effluent collection channels. Samples should be taken from the center of the channels, where the wastewater is normally homogeneous.

Sidestreams

There are no sidestreams associated with the ammonia stripping tower process.

Process Checklist - Ammonia Stripping Tower

1. What is the actual plant flow ________ mgd avg
2. What is total flow through the towers ________ mgd
3. How many towers? ________________
4. What is the flow through each tower ____________ mgd
   ____________ mgd ____________ mgd
5. What type of stripping tower? ( ) counter current ( ) cross flow
   ( ) Other ________________
6. What are tower packing dimensions? ________ Type of packing ________
7. What is ammonia removal? ____________ lbs NH_3
8. What is ammonia removal percentage? ____________ %
9. What is the air flow? ____________ cfm
10. Does previous process have automatic pH adjustment? ( ) Yes ( ) No
11. Are the influent pumps operating properly? ( ) Yes ( ) No. If no, what is problem? ________________
12. Do the mechanical equipment have an adequate spare parts inventory? ( ) Yes ( ) No. If no, what is problem? ________________
    ____
13. How often are the facilities checked? ( ) Once per shift
    ( ) Daily ( ) Other ________________
14. What is frequency of scheduled maintenance? ________________
    ____
15. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ________________
16. What is the general condition of the ammonia stripping system?
    ( ) good ( ) fair ( ) poor
17. What are the most common problems the operator has had with the ammonia stripping process? ________________
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

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9. Parker, D.S., et al, Process Design Manual for Nitrogen Control, USEPA, Technology Transfer, October 1975.

20. CHEMICAL FEEDING AND CONDITIONING

Process Description

Many different chemicals are used for the treatment of municipal wastewaters as listed in Table 20-1. However, many of these are for special conditions and are not often used. The chemicals that are used most frequently include lime, aluminum sulfate (alum), ferric chloride, and sodium hydroxide (caustic soda). Others used less frequently include ferric sulfate, ferrous sulfate (copperas), and sodium aluminate. The selection of which chemical to use depends on the principal purpose of the chemical addition (coagulant or phosphorus removal), the quality of the wastewater, the type of handling and feeding equipment available, and the chemical costs. To minimize chemical costs and to prevent excess use, it is very important that the system include good and reliable chemical feed equipment.

Chemical feed systems are divided into two principal categories, dry feeders and solution feeders. Within each category there are several different methods of feeding the chemical. The most widely used equipment are the volumetric, the belt gravimetric, and loss-in-weight gravimetric feeders, all of which are of the dry feeder type. Liquid feeders usually are metering pumps or orifices. These metering pumps usually are positive displacement, plunger, or diaphragm type pumps.

Lime can be added either before primary treatment or after secondary treatment (as part of an AWT process). As a coagulant used in primary treatment, lime helps to remove SS, phosphorus, heavy metals, grease and viruses. Lime also may be used to adjust the pH of the wastewater, or for sludge conditioning. Lime is never fed as a solution because of its low solubility in water.

Aluminum sulfate may be added to wastewater for coagulation or phosphorus removal. It may be used as the primary coagulant instead of lime, or along with lime. Alum may be added as a filter aid to the influent of a mixed-media filter. It may also be added at several other points in the wastewater treatment process including the primary influent, rapid mix basin, or first stage recarbonation basin. It is available in either dry or liquid form.

Polymers are used as an aid to flocculation, where a light or fine floc settles too slowly. They are also used as filter aids. By adding the right amount of polymer at the right point in treatment, both turdibity and phosphorus removal can be improved.

Like alum and lime, ferric chloride is an effective coagulant used to remove phosphorus and to lower suspended solids. Ferric chloride also can be used as an oxidant to control odor problems coming from hydrogen sulfide. Since ferric chloride is always fed as a liquid, it is normally obtained as a liquid and unloaded pneumatically.

TABLE 20-1. SOME CHEMICALS AND THEIR PRINCIPAL USES IN WASTEWATER TREATMENT

Chemical	Principal use
Activated silica, SiO_2	Coagulation aid
Aluminum ammonium sulfate, $Al_2(SO_4)_3\cdot(NH_4)_2SO_4\cdot 12H_2O$	Coagulation
Aluminum sulfate (alum), $Al_2(SO_4)_3\cdot XH_2O$	Coagulation, phosphorus precipitation
Ammonia (aqua or anhydrous), NH_3 or NH_4OH	Nutrient addition
Ammonium sulfate, $(NH_4)_2SO_4$	Activation of silica
Bentonite clay	Coagulant aid, weighting agent
Calcium hydroxide, $Ca(OH)_2$ (hydrated lime) and calcium CaO (quicklime)	Coagulation, neutralization, phosphorus precipitation
Carbon dioxide, CO_2	Recarbonation, neutralization
Chlorinated ferrous sulfate (Chlorinated Copperas) $Fe_2(SO_4)_3\cdot FeCl_3$	Coagulation
Ferric chloride, $FeCl_3$ or $FeCl_3\ 6H_2O$	Coagulation, phosphorus precipitation
Ferric sulfate, $Fe_2(SO_4)_3\cdot XH_2O$	Coagulation, phosphorus precipitation
Hydrochlorie acid, HCl	Neutralization, pH adjustment
Nitric acid, HNO_3	Neutralization, pH adjustment, nutrient addition
Phosphoric acid, H_3PO_4	Nutrient addition
Polyelectrolytes (polymers)	Flocculation
Sodium aluminate, $Na_2Al_2O_4$	Coagulation, phosphorus precipitation
Sodium carbonate, Na_2Co_3	pH adjustment
Sodium hydroxide (Caustic Soda), NaOH	Neutralization, pH adjustment
Sulfuric acid	Neutralization, pH adjustment, activation of silica

In the biological nitrification-denitrification process, an oxygen demand source such as methanol often is added to the wastewater in order to reduce the nitrates quickly. Methanol may be used either in a column or in a 3-stage reaction basin as described in the Denitrification Section of this manual (Section 18).

Sodium hydroxide (NaOH) is a strong base used to neutralize an acidic wastewater. Without proper neutralization, acid wastewaters can damage treatment facilities and biological treatment processes. Sodium hydroxide also is used for pH adjustment along with other chemicals used in the treatment process.

Typical Design Considerations

The chemical feed systems are designed with four factors in mind:

- Location of chemical addition in the treatment system (whether primary sedimentation, activated sludge, rapid mix or other),
- Purpose of chemical addition,
- Chemical dosage rates, and
- Selection of equipment suitable for chemical used and feeding rate.

The location of the chemical coagulant addition is related to the reason for the addition. Chemicals added in the primary sedimentation basins, activated sludge aeration tanks or an advanced wastewater treatment chemical treatment system (Section 21) are to remove phosphorus. Chemicals added to the secondary sedimentation basin and ahead of filters are to improve removal of suspended solids. Chemical addition in a tertiary step is generally considered to be the most reliable, although it is more expensive.

The dose rate of chemical is determined experimentally by either jar tests or zeta potential tests. Coagulant doses typically are in the following ranges: aluminum sulfate (alum), 75 to 250 mg/l; ferric chloride, 45 to 90 mg/l; and lime, 200 to 400 mg/l.

Typical Performance Evaluation

The chemical feed system should be evaluated for its ability to maintain the desired feed rate per million gallons of waste. Chemical treatment process evaluation is discussed in Section 21 of this manual.

The following illustrates calculation of lime feed rates for a plant where lime recovery by recalcining of lime sludges is practiced:

Plant flow = 15 mgd
Total CaO dosage = 380 mg/l
$Ca(OH)_2$ = 1.32 x CaO; therefore
380 mg/l CaO = 1.32 x 380 = 500 mg/l $Ca(OH)_2$
Makeup lime = 92% CaO
Recalcined lime = 70% CaO
Makeup lime dosage = 25% of total
Recalcined dosage = 75% of total

Makeup lime dosage = 0.25 x 380 mg/l
= 95 mg/l as CaO
95 x 8.34 = 791 lb of CaO/mg
$791 \times \frac{100}{92}$ = 860 lb makeup lime at 92% purity/mg
860 x 15 = 12,900 lbs for 15 mg, lb/day of makeup lime
$\underline{12,900}$ = 536 lb/hr of makeup lime (makeup lime feeder setting)
Recalcined lime dosage = 0.75 x 380 mg/l
= 285 mg/l CaO
285 x 8.34 = 2,377 lb of CaO/mg
$2,377 \times \frac{100}{70}$ = 3,396 lb of recalcined lime at 70% purity/MG
3,396 x 15 = 50,940 lb for 15 MG (lb/day of recalcined lime)
$\underline{50,940}$ = 2,123 lbs/hr of recalcined lime (recalcined lime feeder setting)

The following illustrates the calculation of alum feed rates for a piston feed pump system:

Three alum feed pumps; two dual head and one single head.
Dual head pumps 0-50 gpm at 100% stroke/head
Single head pump 0-11.5 gph at 100% stroke
Plant flow = 15 mgd
Liquid alum strength = 5.4 lb dry alum/gal
Alum dosage = 20 mg/l
Alum dosage = (20 mg/l) x (8.34 lb/gal)
= 167 lb/mg
lb/15 mgd = (167 lb/mg) x (15 mgd)
= 2,505 lb/day
lb/hr = $\frac{2,505 \text{ lb/day}}{24 \text{ hr/day}}$
= 104 lb/hr
gal/hr = $\frac{104 \text{ lb/hr}}{5.4 \text{ lb/gal}}$
= 19 gal/hr
One pump (2 heads) = $\frac{(19 \text{ gal/hr})}{(100 \text{ gal/hr})} \times 100$
= 19 (use 20% stroke setting)

Process Control

Chemical feed systems can be operated either manually, semi-automatically or fully automatically. The method of control for the feed rate can be the pH of the waste stream, in the case of lime addition or simply a dose rate or concentration per million gallons of waste flow. These control methods are discussed in Reference 1.

Maintenance Consideration

Proper and regular maintenance of the chemical feed system is critical to the efficient and trouble free operation of the system. The features of a maintenance program that should insure these conditions are listed below. They do not consider other processes such as recarbonation which are described under separate sections.

1. Spare parts inventory should include at least one set of each type of bearing, grease and water seals, one each of all gaskets, drive belts, isolation pads and springs, one feed pump head.

2. Spilled material (chemicals) regularly cleaned off.

3. Visual inspection each shift of the chemical feeding equipment to check for excessive noise, unequal loading if there is more than one metering pump, chemical leakage, damage to storage tanks, raw materials, mixing tanks or metering pumps.

4. Records to determine the dose rate to the wastewater and also evaluate whether or not this value is changing with time. If the wastewater characteristics remain the same, changing dosages could indicate a problem with the chemical feed equipment.

5. Storage bins and conveyance systems checked regularly to insure air-tightness.

6. Check the calibration of the pH probe each shift to insure the automatic control system is operating correctly.

7. Daily inspection to check for plugged feed lines.

8. All chemical feed lines whether suction, discharge or lines conveying solid or powered materials, flushed or blown out regularly to insure against plugging and solids build-up.

Records

There are no recommended sampling or laboratory tests associated specifically for the chemical feeding systems. All laboratory testing is performed in connection with the process receiving the chemical.

Operating records should include the following:

1. Dose rate for each chemical.
2. Total volume or weight used per day of each chemical.
3. Dilution water volumes.
4. Remaining volumes or weight of chemicals in storage.

Laboratory Equipment

There is no laboratory equipment required specifically for the chemical feed system. However, good plant operation dictates that the composition and purity of the chemicals used should be checked occasionally. Tests for the various chemicals are described in detail in Standard Methods. Also, the EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples are not usually taken from chemical feed systems because there are no tests done on a regular basis. However, the dose rate and chemical concentration being added to the wastewater must be checked at regular intervals. Therefore, samples from the chemical feed lines should be taken using special sampling taps.

Sidestreams

There are no sidestreams associated with chemical storage and feed systems.

Process Checklist - Chemical Feeding and Conditioning

This chemical feeding checklist relates to the liquid phase only. For the chemical feeds for sludge processing, refer to the individual sludge processes.

1. What are actual plant flows? __________ mgd avg. __________ mgd peak.
2. What chemicals are used? ( ) lime ( ) alum ( ) ferric chloride
   ( ) sodium hydroxide ( ) other ______________________________
   ____
3. Where is chemical added? ( ) primary sed. ( ) aeration basin
   ( ) secondary sed. ( ) chemical treatment ( ) Other __________
   ____
4. What is chemical dose? __________ mg/l __________ lbs/mgd
5. What is principal purpose of chemical addition? __________
6. Is chemical feed system automatically controlled? ( ) Yes ( ) No
   If yes, what basic system? ______________________________
7. What type of feed pump used? ______________________________
8. Are the feed pumps on systems operating properly? ( ) Yes ( ) No.
   If no, explain ______________________________
9. Are the storage tanks and conveyance systems operating properly?
   ( ) Yes ( ) No. If no, explain ______________________________
   ____
10. Is there an adequate spare parts inventory? ( ) Yes ( ) No. If
    no, explain ______________________________
11. Is a reserve supply of chemical maintained? ( ) Yes ( ) No
    How many days supply? __________
12. How often are facilities checked? ( ) once per shift ( ) daily
    ( ) Other ______________________________
13. What is frequency of scheduled maintenance? __________
    ____
14. Is the maintenance program adequate? ( ) Yes ( ) No. If no,
    explain ______________________________
15. What is the general condition of the chemical feed facilities?
    ( ) good ( ) fair ( ) bad
16. What are the most common problems the operator has had with the chemical
    feed systems? ______________________________
    ____
    ____
    ____
    ____

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1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

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21. RAPID MIXING, FLOCCULATION AND CLARIFICATION

Process Description

Rapid mixing and flocculation are used in series to optimize chemical treatment of wastewater.

Rapid mixing is done in a small tank with a mechanical mixing device. Sometimes the mixing is done with other equipment such as baffled channels, hydraulic jump mixers, pneumatic (compressed air) mixing, or in-line static mixing devices. The most common type of mixing device is the rotating turbine mixer; propellers are normally used for small volumes, such as the mixing tanks in chemical feed systems discussed before (Section 20); and paddles are usually used for flocculation agitation.

Turbine mixers are like a centrifugal pump without the casing. They force the water outwards to the sides of the tank and create high turbulence and intense fluid shear. The turbine mixer is usually located in the center of the mixing tank and can have various shaped blades. The diameter of the impeller is usually 30 to 50 percent of the smallest dimension of the tank. Baffles are located vertically to the wall of the tank to eliminate vortexing.

Flocculation helps the suspended particles to stick together to make larger clumps of particles (flocs) which will settle out easily in clarifiers. Flocculation is done by controlled agitation or slow mixing of the coagulated wastewater in a tank which contains mechanical agitation devices such as rotating paddles, vertical turbines, or vertical reciprocating mechanisms. The most common type used is the rotating paddle. The paddle agitator is sized so that the sum of the width of each paddle on a wheel equals 25 percent of the water depth of the basin, or the total paddle area is less than 15 to 20 percent of the cross-sectional area of the water (depth x width). The range of speeds at the outside edge of the paddles (peripheral speed) is 0.5 to 4 feet per second (fps). The vertical turbines operate at peripheral speeds of 2 to 4 fps and have a zone of influence of approximately 3 times the turbine diameter on the same plane as the turbine blades. The vertical zone of influence is 4 to 5 times the diameter of the turbine. The flocculation of the suspended particles is caused by the small eddy currents that are formed at the trailing (back) edge of the paddles, turbine blades or reciprocating caps.

Clarification is gravitational settling related to chemical processes. Chemical clarification almost always follows the rapid mix-flocculation steps. It is similar to sedimentation which is described in Sections 5 and 11 of this manual.

Typical Design Considerations

The principal criteria by which the rapid mixing equipment is sized are the velocity gradient, G, and the detention time. Once these have been selected, the type of mixer and impeller are selected and the horsepower can be computed. Typical values for G and the detention times are given in Table 21-1. For these values, the horsepower averages about 0.5 HP per mgd for a turbine. The design for a 10 mgd rapid mixer is shown in Table 21-2.

TABLE 21-1. VELOCITY GRADIENTS (G) FOR RAPID MIX

Application	G fps/ft or sec^{-1}
In-line, instantaneous blending	3,000 to 4,000
Rapid Mixing	
20 sec contact time	700 to 1,000
30 sec contact time	650 to 900
Longer contact time	500 to 700

TABLE 21-2. TYPICAL DESIGN FOR 10 MGD RAPID MIXER

Detention time at maximum flow, in minutes	1.1
Width, in feet	11.0
Water depth, in feet	8.5
Volume, in cubic feet	1,030
Propeller diameter, in inches	38
Propeller capacity, in cubic feet per minute	2,060
Shaft speed, in revolutions per minute	100
Motor horsepower	5
Velocity gradient, G sec^{-1}	360

The principal criteria for the design of the flocculation equipment are also the velocity gradient, G, and the detention time. The type of mixers used will depend upon the wastewater and process flexibility. The flocculation basin is typically divided into 2 to 4 zones, each with a different G value. Typical G values for a 3 zoned system are 100, 60 and 20, with the percentage volumes for the respective zones of 30%, 30% and 40%. Velocities through the flocculation basin should range from 0.35 to 1 ft/sec. Detention times for flocculation typically range from 20 to 40 minutes. The design criteria for a 10 mgd plant flow are shown in Table 21-3. Flocculation velocity gradients for various applications are shown in Table 21-4.

TABLE 21-3. TYPICAL DESIGN FOR 10 MGD FLOCCULATOR

Detention period, in minutes	45
Width, in feet	30
Depth, in feet	10
Length, in feet	140
Volume of tank, in cubic feet	41,778
Mixing zones: 1 in cu ft	12,500
2 in cu ft	12,500
3 in cu ft	16,788
Velocity gradient, G zone 1 sec^{-1}	100
zone 2 sec^{-1}	60
zone 3 sec^{-1}	20

TABLE 21-4. VELOCITY GRADIENTS (G) FOR FLOCCULATION BASINS

Application	G fps/ft or sec^{-1}
Flocculation	
Tertiary wastewater	100* taper to 40
Turb/color removal - no solid recirc.	100* taper to 40
Turb/color removal - solids contact reactors (5% - vol in suspension)	150* taper to 50
Softening - solids contact reactors (10% - vol in suspension)	200* taper to 100
Softening - ultra high solids contact (20% to 40% - vol in suspension)	400* taper to 250

* Drive layout should provide for alternate speeds, allowing selective downward variation from the maximum values shown.

The clarifiers are sized on the basis of the overflow rate and detention time or water depth. The overflow rate for the clarifiers is based on the chemical coagulant used. Typical design values for clarification of a lime treated wastewater for a 10 mgd plant flow are shown in Table 21-5.

TABLE 21-5. TYPICAL DESIGN FOR 10 MGD CLARIFIERS

Type of coagulent	Lime
Number of tanks	2
Overflow rate, gpd/ft^2	903
Detention time, hrs	2
Total surface area, ft^2	11,083
Diameter of tanks, ft	84
Depth of tank, ft	10

Typical Performance Evaluation

The rapid mix, flocculation and clarification operations are typically considered together and are ultimately judged on the suspended solids and phosphorus removal efficiencies. Typical removal efficiencies have been determined and are shown in Table 21-6.

To check these operations, the following simple computations can be made. The equations used are shown in Table 21-7. For easier solution, the power equations have also been presented in graphical form on Figure 21-1. Table 21-8 gives correction factors.

TABLE 21-6. TYPICAL PHOSPHORUS REMOVAL EFFICIENCIES

		Range in percent removals	
Chemical coagulant	Application location	w/o filtration	w/filtration
Lime	Tertiary	95 to 97	97 to 99
Lime + ferric	Tertiary	96 to 98	98 to 99
Alum	Primary sed.	75 to 90	
Ferric chloride	Primary sed.	70 to 90	
Ferric chloride	Secondary sed.	83	
Ferric sulphate	Aeration basin	91	
Alum	Aeration basin	75-85	
Ferric chloride	Aeration basin	75-85	
Lime	Primary sed.	75-90	
Lime + ferric	Primary sed.	90-95	
Lime + ferric	Trickling filter eff.	93.5	

TABLE 21-7. EQUATIONS USED TO EVALUATE RAPID MIX AND FLOCCULATION SYSTEMS

Energy for Mixing by Mechanical Means

Water Power = $P = G^2 V u$ where

Brake Horsepower,

$$P_H = \frac{P}{550 \times E_D \times E_B}$$

Substituting for constants;

Velocity gradient = 4589.4 P/S

P = water power, ft-lb/sec
G = velocity gradient, sec^{-1}
V = volume of tank, cu ft
u = absolute viscosity of liquid, lb-sec/sq ft
= 2.089×10^{-5} at 20°C
E_D= drive efficiency, %/100
E_B= bearing efficiency, %/100
P_H= brake horsepower, HP

Flocculator paddle area

$$A = \frac{2P}{C_D \quad u^3}$$

$$= \frac{561.2\ P_H}{v^3}$$

A = paddle area, sq ft
P = water power, ft-lbf/sec
C_D= drag coeff. = 1.8
= mass density of liquid, $lb\text{-}sec^2/ft^4$
= 62.4
u = relative velocity of paddles, ft/sec
= 0.75 V
v = velocity of paddle tip, fps

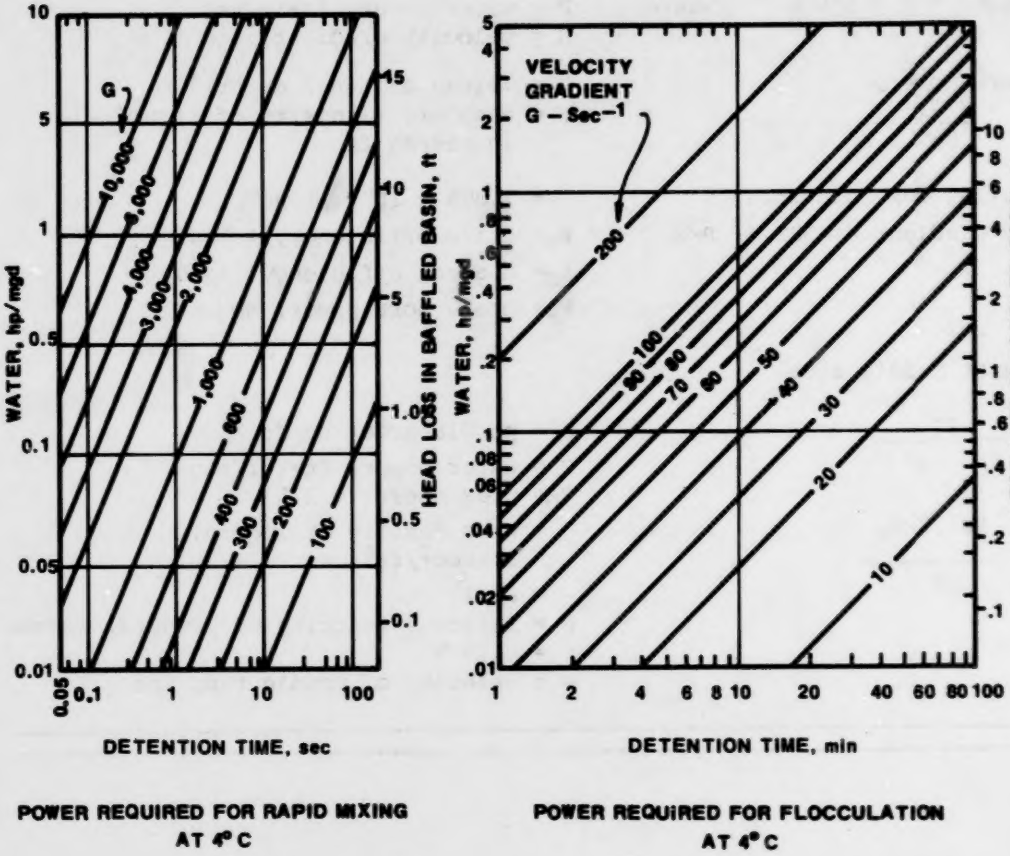


Figure 21-1. Power requirements for rapid mix and flocculation.

TABLE 21-8. TEMPERATURE CORRECTIONS

Multiply values obtained from accompanying graphs for $4^{o}C$ by temperature correction factor stated below to determine horsepower or velocity gradient at any other temperature

Water Temp. ^{o}C	Temperature Correction Factor hp per mgd	 G, sec^{-1}
0	1.14	0.937
1	1.11	0.948
2	1.07	0.966
3	1.03	0.985
4	1.00	1.00
5	0.981	1.02
6	0.940	1.03
7	0.914	1.05
8	0.889	1.06
9	0.863	1.08
10	0.838	1.09
11	0.811	1.11
12	0.794	1.12
13	0.774	1.14
14	0.748	1.16
15	0.729	1.17
16	0.716	1.18
17	0.696	1.20
18	0.678	1.21
19	0.669	1.22
20	0.646	1.24
21	0.629	1.26
22	0.615	1.28
23	0.600	1.29
24	0.586	1.31
25	0.572	1.32
26	0.559	1.34
27	0.547	1.35
28	0.535	1.37
29	0.523	1.39
30	0.512	1.40

1. Collect the required base information for the rapid mix, flocculation, and clarifiers.
Plant flow rate = 5 mgd
Phosphorus influent concentration = 10 mg/l as P
Phosphorus effluent concentration = 0.6 mg/l as P
Rapid mix tank dimensions = 2 tanks at 6' x 6' x 6' water depth
Rapid mixer horsepower = 1 HP per tank
Flocculator dimensions = 2 tanks of 40' x 20' x 10' water depth
Paddle area = 47 sq ft
Mixer horsepower = 1st stage = 2 HP, 2nd stage = 1/2 HP
Clarifier diameter = 60 ft
Number of clarifiers = 2
Depth of clarifier tank = 12 ft

2. Compute detention time and velocity gradient for rapid mix.
Volume = 2 x 6' x 6' x 6' = 432 cu ft

$$\text{Detention time} = \frac{432 \times 7.48 \times 24 \times 60 \times 60}{5 \text{ mgd}}$$

= 56 sec
Water horsepower = 2 x 0.8 = 1.6 HP
Velocity gradient, G = 4589.4 x P/V
= 4589.4 x 2/432
= 312 sec^{-1}
Water HP/mgd = 0.32
From curve, using 0.32 and 56 sec, G = 260
Correction factor from Table 21-9 for 20°C = 1.24
G value = 1.24 x 260 = 322 sec^{-1}

3. Compute detention time, velocity gradient, and check paddle area for flocculation.
Total volume = 2 x 40' x 20'x 10' = 16,000 cu ft
= 8000 cu ft per basin

$$\text{Detention time} = \frac{16{,}000 \times 7.48 \times 24 \times 60}{5 \text{ mgd}}$$

= 34.5 min
Assumed two flocculation stages, using half volume of each tank.
(From Table 21-7)
1st stage G = 4589.4 P/V
= 4589.4 2/4000
= 102.6 sec^{-1}
2nd stage G = 4589.4 0.5/4000
= 51.3 sec^{-1}
Check value from graph.

$$\text{Ratio of water hp/mgd} = \frac{2 \times 0.8}{2.5} = 0.64$$

Using 0.64 and detention time of 17 min
From graph, G = 88 sec^{-1}
Correction factor to 20°C from Table 21-8 = 1.24
G = 1.24 x 88 = 109 sec^{-1}
Check paddle area using equations from Table 21-7.

$$\text{Paddle area, } A = \frac{561.2\, P_H}{V^3} = \frac{561.2 \times 2}{3^3} = 41.5 \text{ sq ft}$$

4. Determine overflow rate and detention time for the clarifier.

$$\text{Surface area} = \frac{2 \times \quad \times D^2}{4}$$

$$= \frac{2 \times \quad \times 60 \times 60}{4} = 5655 \text{ ft}^2$$

$$\text{Overflow rate} = \frac{5 \times 10^6}{5655} = 884 \text{ gpd/ft}^2$$

$$\text{Volume} = \text{Surface area} \times \text{depth}$$

$$= 5655 \times 12 \times 7.48 = 507{,}593 \text{ gallons}$$

$$\text{Detention time} = \frac{507{,}593}{5 \times 10^6} \times 24 = 2.44 \text{ hours}$$

Check paddle area as percent of cross-section area.

$$\text{Percent} = \frac{41.5 \times 100}{20 \times 10} = 20.8\%$$

Process Control

There are usually no adjustments that can be made to the rotational speed of the mixer to change the value of the velocity gradient, G, because the drive motor and impeller almost always have a constant speed. The only adjustments to the overall process efficiency is the rate of chemical addition to the rapid mix operation. Overfeeding chemicals can compensate for a poor mixing system.

The only operational adjustment available for the control of the flocculation system is the rotational speed of the mixers. The velocity of flocculator mixers must be carefully controlled. Very high velocity gradients will prevent a settleable floc from forming. To produce compact floc particles, the highest velocity gradient should be used which still produces a strong floc.

The only control of the clarification operation is the rate at which the chemical solids are pumped from the system. The frequency of pumping and the length of time of each pumping sequence determines the solids concentrations in the chemical sludge, or mud, which in turn can have a major effect on downstream treatment processes such as thickening, dewatering, and recalcination in the case of lime mud. Pumping too frequently or for too long a time will cause a "thin" sludge (low solids concentration) which can reduce the capacity of sludge handling processes; can cause hydraulic overloads to sludge thickening processes; and can cause greater fuel consumption in the incinerators or recalciners. If the sludge is not pumped often enough, it can turn anaerobic and release phosphorus back into the water.

Maintenance Considerations

Proper maintenance is important for trouble free and efficient treatment plant operation. Scale build-up on the mixers can severely reduce the effectiveness of the operation. The elements of a good maintenance program are listed below.

1. Spare parts inventory should include at least one set of each type of bearing, grease and water seals, all necessary gaskets for replacement of parts, paddles and drive belts.

2. Visual inspection each shift of the rapid mix, flocculation and clarification equipment to check the equipment for misalignment, excessive noise, and unequal loading of each operation if there are two or more of each.

3. Regular checking and calibration of pH control equipment for lime systems.

4. All sample lines flushed regularly to flush out material, such as chemical floc, that may have entered the lines.

Records

The recommended sampling and laboratory tests are shown in Figure 21-2 for the rapid mix, flocculation, and clarification operations.

Other operating records should include the following:

1. Influent flow to rapid mix
2. Chemical type and dosage
3. Estimated rotational speeds of mixers

Laboratory Equipment

The laboratory should include the following minimum equipment to monitor the chemical treatment system.

1. Clinical centrifuge
2. pH meter
3. Titration equipment

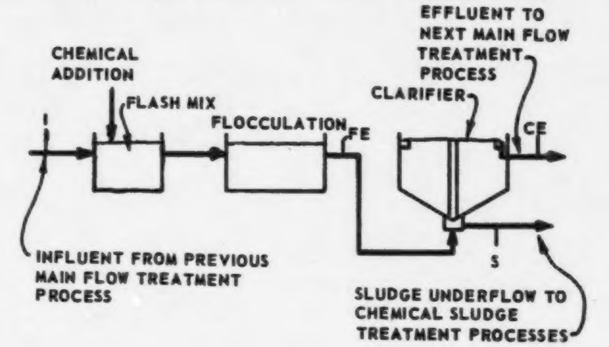
The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be taken from the center of the influent and effluent channels where the wastewater is normally homogeneous and the channel velocities are high. If there are no channels, sample from the center of the flow distribution boxes. The effectiveness of the chemical addition should be as measured by the suspended solids concentration at the outfall from the flocculation tank. Samples of the chemical sludge should be taken from special sample taps in the pump discharge lines. The solids concentration in the sludge should be determined and recorded.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

CHEMICAL TREATMENT


EFFLUENT TO
NEXT MAIN FLOW
TREATMENT
PROCESS
CHEMICAL
ADDITION
FLASH MIX
CLARIFIER
FLOCCULATION
FE
I
CE
S
INFLUENT FROM PREVIOUS
MAIN FLOW TREATMENT
PROCESS
SLUDGE UNDERFLOW TO
CHEMICAL SLUDGE
TREATMENT PROCESSES

NOTE: CONSIDER AS INDIVIDUAL UNIT PROCESSES

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	pH	ALL	Mn	FE	Mn	P
	pH	ALL	1/D	I CE	G	H
	ALKALINITY	ALL	2/W	I PE	24C	H
	SUSPENDED SOLIDS	ALL	1/D	FE CE	24C	H
	JAR TEST	ALL	[1]	I	24C	P C
	HARDNESS	ALL	1/W	I PE	24C	H
	TURBIDITY	ALL	R	I CE	R	P
	SLUDGE VOLUME LAB CENTRIFUGE	ALL	3/D	S	G	P
	TOTAL SOLIDS	>1	1/W	S	G	P
	TOTAL SOLIDS	1	3/W	S	G	P
	FLOW	ALL	R	S	R	P
OPTIONAL	CALCIUM CONTENT[2]	ALL	[3]	LS	G	C
	CHLORIDES[4]	ALL	1/W	I PE	24C	H
	SULFATES[5]	ALL	1/W	I PE	24C	H
	TOTAL-P[6]	ALL	3/W	I PE	24C	H
	ORTHO-P[6]	ALL	3/W	I PE	24C	H

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
FE = FLOCCULATION EFFLUENT
LS = LIME FROM SUPPLIER (INCLUDE W/FLASH MIX PROCESS TESTING)
CE = CLARIFIER EFFLUENT
PE = PLANT EFFLUENT
S = SLUDGE UNDERFLOW

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. SPOT CHECK
2. IF LIME IS USED
3. WHEN LIME IS DELIVERED BY SUPPLIER
4. IF FERRIC CHLORIDE IS USED
5. IF ALUM OR FERRIC SULFATE IS USED
6. IF PROCESS IS DESIGNED TO CONTROL THIS PARAMETER

Figure 21-2

Sidestreams

The only sidestream from the chemical treatment system is the chemical sludge or mud pumped from the clarifier. The solids concentration is important since it effects the volume of liquid to be pumped. For example, increasing the solids concentrations from 1% to 2% halves the volume of liquid to be pumped. The amount of chemical sludge produced is entirely dependent upon the type of chemical used as the coagulant. Typically, the solids concentrations from the clarifier range between 1 and 2 percent.

Process Checklist - Rapid Mix, Flocculation and Clarification

1. What is plant flow? ____________ mgd avg.
2. What is total flow through chemical treatment system? ________ mgd
3. How many units are there of each operation? ____________
4. What is the flow through of each unit? ____________ mgd
5. If flow divided equally? ( ) Yes ( ) No. If no, what is problem? ____________
6. What type of rapid mixer? ( ) turbine ( ) propeller ( ) air ( ) other ____________
7. What type of flocculator? ( ) turbine ( ) paddles ( ) other ____________
8. What are dimensions of rapid mix tank? ____________
9. What are dimensions of flocculation tank? ____________
10. What are dimensions of clarifier? ____________
11. What is chemical coagulant? ( ) lime ( ) alum ( ) ferric chloride ( ) ferric sulphate ( ) other ____________
12. What is chemical dose? ________ ________ mg/l
13. What are detention times? Rapid mix ____________ sec., flocculation ____________ min., clarifier? ____________ hrs.
14. What is clarifier overflow rate? ____________ gpd/ft^2
15. What is volume of sludge pumped? ____________ gallons/day
16. What are solids concentration? ____________ percent
17. Are mixers operating properly? ( ) Yes ( ) No. If no, explain ____________
18. Are sludge pumps operating? ( ) Yes ( ) No. If no, explain ____________
19. Is chemical feed system operating correctly? ( ) Yes ( ) No. If no, explain ____________
20. Is there an automatic chemical feed control system? ( ) Yes ( ) No If yes, what kind? ____________
    Is it operating? ( ) Yes ( ) No. If no, explain ____________
21. Do mechanical equipment have adequate spare parts inventory? ( ) Yes ( ) No. If no, explain ____________
22. Is the sludge pumping stations adequately ventilated and illuminated? ( ) Yes ( ) No. If no, explain ____________
23. How often are the facilities checked? ( ) Once per shift ( ) daily ( ) other ____________
24. What is the frequency of scheduled maintenance? ____________
25. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ____________

26. What is the general condition of the chemical treatment system?
( ) good ( ) fair ( ) poor

27. What are the most common problems the operator has had with the chemical treatment system?____
____
____
____
____

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22. RECARBONATION

Process Description

Recarbonation is the process of lowering the pH of lime treated wastewaters to neutral (pH = 7) conditions by the injection of carbon dioxide into the wastewater. The process is used to prevent calcium problems on equipment and structures that follow either lime treatment or ammonia stripping. Downstream processes, such as filtration, carbon adsorption, reverse osmosis and others, operate most efficiently when the pH is at or slightly below neutral (pH = 7).

Recarbonation can be carried out in either one or two stages. In single-stage recarbonation, the pH of the water is reduced from a range of 10 to 11.5 down to about 7 by applying the carbon dioxide to one recarbonation basin. This results in increased calcium hardness of the effluent.

Two-stage recarbonation uses two contact basins for treating the wastewater with the carbon dioxide. The two basins are separated by an intermediate settling tank. In the first-stage, the pH of the wastewater is lowered to about 9.3. At this pH, calcium carbonate is insoluble and a floc readily forms. The wastewater then enters the settling basin in which the chemical reactions continue and the calcium carbonate floc settles out. The effluent from the settling tank enters the second stage recarbonation basin where carbon dioxide is added to further reduce the pH.

The two-stage recarbonation process is normally used when very low levels of phosphorus are required in the final effluent. The phosphorus is adsorbed on the calcium carbonate floc formed in the first-stage basin and removed in the settling basin.

The usual source of carbon dioxide for recarbonation is the stack gas from either sludge incinerators or lime recalcination furnaces. When stack gas is not available, special carbon dioxide (CO_2) generators, underwater natural gas burners, or liquid CO_2 can be used.

Typical Design Considerations

The design criteria are related to the mode of operation, the number of stages, the basin sizes, and the carbon dioxide requirement and source.

The mode of operation affects the basin sizing if an intermediate settling tank is included. For single-stage systems, the reaction or recarbonation basin should have a detention time of 5 min with a minimum water depth of 8 feet. If submerged burners or liquid CO_2 are used the water depth should be 10 to 12 feet. The reaction basin should be followed by a basin having a detention time of about 15 min to permit complete reactions. The second basin does not need settling or sludge collection equipment.

Two-stage systems require the same 5 min detention time in both the first and second stage basins and the same criteria for water depth as for the single stage. The intermediate settling basin requires a detention time in the range of 30 to 40 min, and a maximum overflow rate in the range 2000 to 2400 gpd/ft^2.

The amount of carbon dioxide required to reduce the pH from about 11 to 7 depends upon the alkalinity of the wastewater, lime dose and the ammonia (NH_3) concentration.

The sources of carbon dioxide - stack gas, pressure generators, submerged underwater burners and liquid carbon dioxide - are discussed in Reference 1.

Typical Performance Evaluation

The effectiveness of a recarbonation systems is based on its ability to control and reduce the pH of the water to the desired value or range of values. If the pH is within the limits of 9.2 to 9.5 and 6.5 to 7.5 for the two-stage system and 6.5 to 7.5 for the single-stage system, then the recarbonation facility is operating correctly.

Occasionally the CO_2 requirement or use should be checked and compared to the theoretical requirements.

1. Collect plant information.
   Plant flow 5 mgd
   pH = 11.7
   Alkalinity (mg/l as $CaCO_3$)
     $OH^- = 380$
     $CO_3^{2-} = 120$
     $HCO_3^- = 0$
   Ammonia = 25 (mg/l as N)
   CO_2 content of stack gas = 10%
   Blower capacity = 1800
   Loss to atmosphere = 20%
   Temperature of cooled stack gas = 110°F

2. Determine lbs of CO_2 required to reduce pH to 7

$$\begin{aligned} 7.4 \times 380 &= 2812 \\ 3.7 \times 120 &= 444 \\ 25.4 \times 25 &= \underline{635} \\ & 3891 \text{ lb/million gallons per day} \end{aligned}$$

   CO_2 requirement = 5 x 3891 = 19,455 lb/day

3. Determine amount of stack gas that must be compressed to deliver 19,455 lbs/day.

$$\text{Stack gas} = 19{,}455 \times \frac{100}{10} = 194{,}550 \text{ lb/day}$$

4. Determine volume of stack gas, in cfm, required at 14.7 psia and $60^{o}F$ ($520^{o}K$)
   Stack gas flow $= \frac{194,550}{0.116 \times 1440} = 1165$ scfm

5. Convert stack gas flow to conditions at the plant site.
   Temperature correction: $\frac{110 + 460}{60 + 460} \times 1165 = 1277$ cfm
   Altitude correction: $\frac{14.7}{11.6} \times 1277 = 1618$ cfm

6. Allowance for the CO_2 loss to atmosphere increases the required stack gas volume by 20%.
   Stack gas volume = 1.2 x 1618 = 1941 cfm.

7. Based on these computations, the existing compressors do not have sufficient capacity.

Process Control

Using pH measurements, control of CO_2 dosages may be determined by trial and error. In two-stage systems, the CO_2 flow should be set to reduce the pH in the second-stage recarbonation basin. This flow should be split between the two stages to get a pH of 10 in the center of the intermediate settling basin. Once the CO_2 valves are set for a proper split, they should need very little other adjustment for changes in total CO_2 flow. At average wastewater temperatures, about 15 min are needed for all CO_2 bubbles to react completely to form calcium carbonate. This is why pH is measured at the middle of the settling basin rather than at the entrance.

The pH control can also be automatic. Control on the output of the compressors are sometimes used, but normally, surplus stack gas is vented to atmosphere.

Maintenance Considerations

The maintenance program should include the following items.

1. Spare parts inventory should include at least the following items: one set of each type of bearings, grease seals, water seal rings, one set of all gaskets, mechanical seals, nozzles for CO_2 dissolution, and items of the control system.

2. Daily inspection of the recarbonation basins to insure that the nozzles are not plugged.

3. Inspection each shift to check the calibration of the automatic pH control instrumentation.

4. Daily readings of compressor motor run times recorded from elapsed time meters. These times can be used for scheduling maintenance work

and to insure that the motors are used evenly. Also, these run times can be used to estimate the volume of stack gas compressed and released into the recarbonation basins.

5. Periodic performance tests run on the compressors to insure that they are operating at the same capacity as they were when originally supplied to the plant.

Records

The recommended sampling and laboratory tests are shown in Figure 22-1 for the recarbonation facilities. The same tests would be used for a single-stage recarbonation system.

Other operating records should include the following:

1. Influent flow to the recarbonation basins
2. Calcium carbonate sludge volumes
3. Carbon dioxide useage

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor the recarbonation system.

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. Drying oven
4. Dessicator
5. pH meter

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected from the center of the influent and effluent channels where the wastewater is normally homogeneous and the channel velocities are sufficiently high to avoid solids deposition. To check the effectiveness of the first-stage recarbonation basin, grab samples from the center of the settling basin should be measured for pH.

Samples of the calcium carbonate sludge should be taken from sample taps in the pump discharge lines. The solids concentration in the sludge should be determined.

Sidestreams

The only sidestreams from the recarbonation process is associated with the two-stage process. The intermediate clarifier captures calcium carbonate

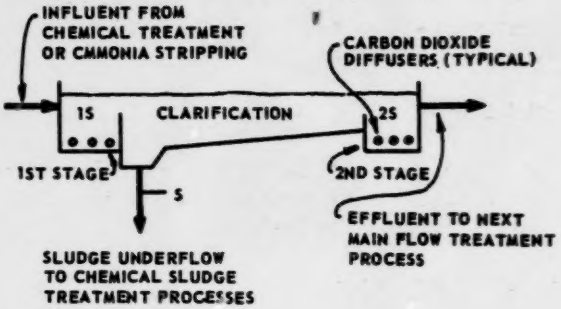
ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
pH	ALL	Mn	P1S P2S	Mn	P
TOTAL SOLIDS LAB CENTRIFUGE	ALL	3/D	S	G	P
TOTAL SOLIDS	ALL	1/W	P2S	24C	H
DISSOLVED SOLIDS	ALL	1/W	P2S	24C	H
ALKALINITY	ALL	1/D	P1S P2S	24C	H
AMMONIA	ALL	1/D	P1S P2S	24C	H

TWO STAGE RECARBONATION


INFLUENT FROM CHEMICAL TREATMENT OR CMMONIA STRIPPING
CARBON DIOXIDE DIFFUSERS (TYPICAL)
1S
CLARIFICATION
2S
1ST STAGE
S
2ND STAGE
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
SLUDGE UNDERFLOW TO CHEMICAL SLUDGE TREATMENT PROCESSES

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

P1S = PROCESS FIRST STAGE
P2S = PROCESS SECOND STAGE
S = SLUDGE UNDERFLOW

C. METHOD OF SAMPLE

24C - 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 22-1

sludge (sometimes termed mud) and returns this to the gravity thickener and then to the recalcination furnace where the lime (CaO) is produced. The chemical sludge has a concentration in the range of 1 to 2 percent. The sludge from this process is actually equivalent to the amount of lime added in excess of the amount required to react with the alkalinity of the wastewater and raise the pH to about 11.3 at the chemical clarification process.

Process Checklist - Recarbonation

1. What is actual plant flow? __________ mgd avg.
2. What is total flow through recarbonation system? __________ mgd
3. What is flow through each unit? _______________ mgd _______________ mgd _______________ mgd _______________ mgd
4. What is type of system? ( ) single-stage ( ) two-stage
5. What are basin dimensions? ____________ 1st stage __________ 2nd stage _______________ intermediate clarifier.
6. What is CO_2 useage? _______________ lbs/day
7. What are the concentrations of chemicals? _______________ mg/l OH^-; _____________________ mg/l CO_3^{2-}; _________________ mg/l HCO_3^-; ____________________ mg/l NH_3
8. What type of CO_2 system? ( ) stack gas ( ) submerged burners ( ) pressure generators ( ) liquid CO_2 ( ) other __________
9. What is estimated CO_2 loss to atmosphere? __________________ percent
10. What is CO_2 concentration in stack gas? __________________ percent
11. What are detention times? ________ min., 1st stage; __________ min. 2nd stage; __________________ min. clarifier
12. What is clarifier overflow rate? _________________ gpd/ft^2
13. What is volume of sludge pumped? _________________ gallons/day
14. What is sludge concentration? __________________ percent
15. Are sludge pumps operating? ( ) Yes ( ) No. If no, explain ______________________________
16. Are CO_2 compressors operating? ( ) Yes ( ) No. If no, explain ______________________________
17. Is CO_2 system working properly? ( ) Yes ( ) No. If no, explain ______________________________
18. Do mechanical equipment have adequate spare parts inventory? ( ) Yes ( ) No. If no, explain ______________________________
19. Are the housings associated with this system adequately ventilated? ( ) Yes ( ) No. If no, explain ______________________________
20. How often are the facilities checked? ( ) Once per shift ( ) daily ( ) other ____________________________
21. What is frequency of scheduled maintenance? ______________________________
22. Is the maintenance program adequate? ( ) Yes ( ) No. If no, explain ______________________________
23. Are the recarbonation basins covered? ( ) with air tight structure ( ) with open type structure ( ) no covering
24. What is the general condition of the recarbonation system? ( ) good ( ) fair ( ) poor
25. What are the most common problems the operator has had with the recarbonation system? ______________________________

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Miorin, A.F., et al, Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation (1977).

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7. Culp, Gordon L., and Culp, Russell L., New Concepts in Water Purification, Van Nostrand Reinhold, 1974.

8. Culp, Russell L., Wesner, G. M., and Culp, Gordon L., Handbook of Advanced Wastewater Treatment, Van Nostrand Reinhold, 1978.

9. CH2M Hill, Process Capacity and Ammonia Removal Study, South Tahoe Public Utility District, 1977.

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23. LAND APPLICATION OF WASTEWATERS

Process Description

Land treatment systems are designed or operated for different reasons. The system can be used as a disposal area with no surface discharge. The loading rate may be set at the maximum for soil infiltration rates, or lowered so that crop growth can be optimized. Overland flow systems are designed for treatment with surface discharge. The different systems can be grouped into three categories as follows:

- Irrigation
- Overland Flow
- Infiltration-Percolation

Irrigation systems are the most flexible. These can be used for high or low rate application. They can be used for disposal or treatment with discharge. Irrigation systems operated for crop growth can be used as high rate disposal systems during the off-season.

Irrigation is by sprinklers or surface spreading. The sprinkler system may be solid set with underground piping, hand movable with light-weight piping and quick couplers, or mechanically moving such as center pivot, travelling gun, or side-wheel roll. Of the mechanical systems, the center pivot system is the most widely used for wastewater irrigation.

Surface spreading may be by ridge and furrow, border check, or controlled flooding. These require runoff control and recycling if no surface discharge is allowed.

Typical overall removals of pollutants by irrigation are:

BOD	98%
COD	80%
Suspended solids	98%
Nitrogen	85%
Phosphorus	95%
Metals	95%
Micro-organisms	98%

In an overland flow system, the wastewater is sprayed over a hillside with a 2-6% slope. It flows slowly down the hill and through the vegetation.

The primary filtering mechanism for overland flow systems is the plant growth rather than the soil mantle. Treatment efficiencies can vary considerably but the following values can be attained with a properly designed, well run system:

BOD	92%
Suspended solids	92%
Nitrogen	70-90%
Phosphorus	40-80%
Metals	50%

Application of overland flow systems is somewhat limited in that a 2-9% slope is required and a clayey soil desirable. These same conditions are very poor sites for irrigation systems.

In infiltration-percolation systems, the groundwater is recharged by percolation of wastewater (after secondary treatment) using spreading basins. This process is strictly for disposal with no surface runoff. Wastewater applied to the land for the purpose of disposal is also being treated by infiltration and percolation. Removals by this system are:

BOD	85-99%
Suspended solids	98%
Nitrogen	0-50%
Phosphorus	60-95%
Metals	50-95%

Infiltration-percolation is mostly a groundwater recharge system, and does not utilize nutrients through crop growth.

Land application systems usually include the following parts:

- Preapplication treatment
- Transmission to the land treatment site
- Storage for the wastewater during the non-irrigation season
- Distribution over the irrigated area
- A system to recover the renovated water
- The crop system

Typical Design Considerations and Performance Evaluation

Loading rates are highly variable depending on climate, crop grown (if any), soil type, and system objective. Table 23-1 shows typical design criteria. If crops are grown (low rate irrigation) and the soils have a high infiltration capacity, then high rate irrigation can be practiced in the off season. There are other special situations where loading rates would be adjusted; those shown cover the ranges to be expected.

The major concerns for operation of a land treatment system are adequate application area, adequate storage for periods when application is not possible, and adequate equipment to apply water during available time period. These three concerns are more critical for crop irrigation than the other systems due to the need to harvest and replant the next crop. Therefore, the following example calculations are set up for a crop growing system.

TABLE 23-1. TYPICAL DESIGN CRITERIA FOR IRRIGATION, INFILTRATION-PERCOLATION, AND OVERLAND FLOW SYSTEMS FOR MUNICIPAL WASTEWATER

Factor	Irrigation		Infiltration-percolation	Overland flow
	Low-rate	High-rate		
Liquid loading rate, in/wk	0.5 to 1.5	1.5 to 4.0	4 to 120	2 to 9
Annual application, ft/yr	2 to 4	4 to 18	18 to 500	8 to 40
Land required for 1-mgd flowrate, acres[a]	280 to 560	62 to 280	2 to 62	28 to 140
Application techniques	Spray or surface		Usually surface	Usually spray
Vegetation required	Yes	Yes	No	Yes
Crop production	Excellent	Good/fair	Poor/none	Fair/poor
Soils	Moderately permeable soils soils with good productivity when irrigated		Rapidly permeable soils, such as sands, loamy sands, and sandy loams	Slowly permeable soils, such as clay loams and clays
Climatic constraints	Storage often needed		Reduce loadings in freezing weather	Storage often needed
Wastewater lost to:	Evapotranspiration percolation		Percolation	Surface runoff and evaporation with some percolation
Expected treatment performance				
EOD and SS removal	98 + %		85 to 99%	92 + %
Nitrogen removal	85 + %[a]		0 to 50%	70 to 90%
Phosphorus removal	80 to 99%		60 to 95%	40 to 80%

[a] Dependent on crop uptake

1. Application area requirement:
   Given:
   a. Location - Minden, Nevada
   b. Crop - alfalfa
   c. Crop moisture requirement - 4 ft/yr[(1)] above natural precipitation
   d. Irrigation efficiency - 80%[(2)]
   e. Effluent quantity - 5 mgd

$$\text{Area, acres} = \frac{5 \text{ mgd} \times 365 \text{ days/yr} \times 3.07 \text{ ac. ft./mil gal} \times 0.80}{4 \text{ ft/yr}}$$

$$= \underline{1120 \text{ acres}}$$

2. Storage requirement:
   Given:
   a. Growing season - 180 days

   $\text{Storage, mil gal} = 365 - 180 \text{ days/yr} \times 5 \text{ mgd}$

   $= \underline{925 \text{ mil gal}}$

3. Application equipment capacity:
   Given:
   a. Maximum month - July
   b. Maximum water consumption - 10 inches/month
   c. Irrigation efficiency - 80%
   d. Acreage under irrigation - 1120 acres
   e. Percent operating time - 70% (allowance for changing fields)

Equipment capacity, gpm =

$$\frac{10 \text{ in./mo} \times 1120 \text{ acres} \times 10^6 \text{ gal/mil gal}}{0.80 \times 12 \text{ in/ft} \times 31 \text{ days/mo} \times 24 \text{ hr/day} \times 60 \text{ min/hr} \times 3.07 \text{ ac ft/mil gal}}$$

$$= 8513 \text{ gpm}$$

Once the above values are determined, individual system limitations must be applied to refine the above values. For example, the application area may be adjusted if application can continue after the growing season is over. If effluent application is continued then less area will be necessary. Also, the system must be planned around crop planting and harvesting periods, including crop drying prior to harvest.

Other design criteria, in addition to loading rates are related to effluent qualities and precautions necessary to prevent public health problems or nuisance conditions from developing. These criteria are applied to the adjunct facilities such as pretreatment, storage, and recovery of renovated water. Pretreatment requirements vary among the states and with the intended use of the crop grown (if any). Most areas require at least primary treatment or secondary treatment by oxidation ponds or aerated lagoons. Some areas require higher secondary effluent quality.

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(1) Ft/yr is used by irrigators meaning acre-feet/acre-year.

(2) Percent of applied water available for crop use.

Storage ponds may be lined depending on the soil type and proximity of groundwater aquifers. Aeration systems should be provided. The magnitude of the aeration requirement depends on the amount of pretreatment provided. Storage ponds or reservoirs should be inspected as treatment ponds.

Recovery of renovated water is done by underdrains, recovery wells, and/or tailwater return systems. Irrigation efficiency used earlier to determine area requirements would be increased depending on the degree of renovated water recovery. Irrigation efficiency is defined as the amount of water consumed by the crop divided by the amount of water passing through the soil surface. Thus, if all water passing through the root zone is recovered and returned then more application area will be necessary.

Process Control

Operation of irrigation systems requires good crop management and proper wastewater pretreatment. Personnel must have a working knowledge of farming practices, and principles of wastewater treatment. Seasonal (often weekly) changes in operation must respond to changing crop requirements for nutrients and water; monitoring must be done to determine removal efficiencies and to forecast buildups of toxic compounds; and the system must be continuously watched to avoid problems of ponding, runoff, or mechanical breakdowns.

Close cooperation between the treatment system management and the farm operation is always needed. Irrigation must be scheduled with farm operations such as planting, tilling, spraying and harvesting, for successful operation. Farm specialists can be helpful in setting up the management of the crops, soil, and irrigation portions of the operation.

Proper cropping is also important for good nitrogen removal to prevent pollution of groundwater. Nitrate nitrogen can be removed by growing and removing from the area a crop which takes up nitrogen. Nitrogen removal by crops is dependent on the length of growing season, crop type, and the availability of nitrogen.

Operation of infiltration-percolation systems is much simpler. Process control consists of rotating areas to allow drying and access for discing equipment. Areas should be allowed to dry out annually so the soil can be broken up to prevent clogging.

Maintenance Considerations

Maintenance concerns mainly pumps and pipelines. A good maintenance program should include the following:

1. Pre-startup inspection of all equipment.
2. Schedules set up to carry out manufacturers' recommendations for maintenance of pumps, motors, valves, and sprinklers (if used).

3. Lubrication program for regular oil changes, cleaning and flushing of gear housing, removal and cleaning of oil pump strainers, checking of oil seals for leaks.
4. Keeping maintenance records current.
5. Procedure for preparing equipment for winter shut down.
6. Farm equipment maintenance schedule.
7. Access road, dike, and/or levee maintenance program.

Records

Recommended sampling and laboratory tests are shown in Figure 23-1.

Other operating records should include:

1. Influent flow quantity (from storage)
2. Volume of water recovery from wells or drainage system
3. Frequency and duration of operation of pumps

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor land application:

1. Analytical balance
2. Blender
3. Fume hood
4. Incubator
5. Kjeldahl digesting and distilling apparatus
6. Oven
7. pH meter
8. Pump (vacuum-pressure)
9. Spectrophotometer
10. Sterilizer
11. Titrator-amperometric

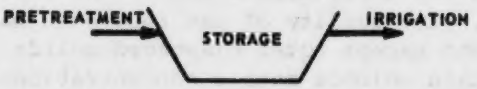
Sampling Procedures

Samples should be collected at points where the wastewater is well mixed such as at the center of channels of flow where velocities are high. The storage pond sampling should be done near the middle. Soil samples should be taken at several locations so an average value may be determined and extremes eliminated. Sample collectors and containers should be clean.

A wide mouth sample collector of at least 2 inches should be used for wastewater samples. Where automatic samplers are used, it is important to keep the sampler tubes clean.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

LAND TREATMENT



		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TEMP^1	ALL	1/D	I E	G	H
	pH^1	ALL	1/D	I E	G	H
	BOD^1	ALL	2/W	I	24C	P
	SUSPENDED SOLIDS	ALL	3/W	I	24C	P
	NH$_3$N^2	ALL	1/W	E	24C	P
	ORG-N^2	ALL	1/W	E	24C	P
	NO$_3$-N^2	ALL	1/W	E	24C	P
	TOTAL-P^2	ALL	1/W	E	24C	P
	ORTHO-P^2	ALL	1/W	E	24C	P
	K	ALL	1/W	E		P
	SOIL CONDUCTIVITY	ALL	S	S	R	P
	COLIFORM	ALL	1/W	S	G	P
OPTIONAL	DISSOLVED SOLIDS	ALL	2/W	E	24C	H
	ALKALINITY	ALL	2/W	E	24C	H
	HEAVY METALS	ALL	S	E S	24C	H
	BORON	ALL	Q	E	24C	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
Q = QUARTERLY
S = SEMI ANNUAL
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT TO STORAGE POND
E = EFFLUENT FORM STORAGE POND
S = SOIL

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 23-1

Tensiometers or lysimeters are used to control application rates. Either of these can be used with automatic controls to start or stop sprinklers for precise control of irrigation.

Groundwater monitoring is variable depending on the local health agency requirements. Generally speaking, pathogen bacteria, nitrates, and metals are measured. Monitoring is accomplished by small wells located around or thoroughout the application site.

Sidestreams

The only sidestream with this process is recovered tailwater or pumped drainage. This water can be discharged to surface streams if allowed or recycled to the irrigation system. The volume will be 10-14% of the applied effluent. The quality of the renovated water will lower the constituent concentrations except total dissolved solids. Depending on the geology of the area certain soluble metals concentrations may increase in pumped sub-surface drainage water.

Process Checklist - Land Application

A. Pretreatment - see appropriate section elsewhere in this guide.

B. Storage
   1. Is scum controlled? ( ) Yes ( ) No
   2. Are odors present? ( ) Yes ( ) No
   3. Are levees free of excessive weed growth? ( ) Yes ( ) No
   4. Are there indications of levee erosion? ( ) Yes ( ) No
   5. Are there planned programs for rodent and insect control? ( ) Yes ( ) No

C. Pumping
   1. Frequency of maintenance __________/Year
   2. Is maintenance program adequate? ( ) Yes ( ) No
   3. Is standby pumping provided? ( ) Yes ( ) No

D. Irrigation System
   1. Do sprinklers clog frequently? ( ) Yes ( ) No
   2. Does distribution piping allow flexibility to maintain operation in one area while another is down? ( ) Yes ( ) No
   3. Are flood irrigation levees maintained? ( ) Yes ( ) No
   4. Are nuisance weed growths controlled? ( ) Yes ( ) No
   5. Is there a planned procedure for off season shut down and following season startup? ( ) Yes ( ) No
   6. Do any areas appear to lack moisture? ( ) Yes ( ) No. Have excess moisture? ( ) Yes ( ) No
   7. Is a rotation plan in effect for changing infiltration-percolation cells? ( ) Yes ( ) No

E. Farming (If applicable)
   1. Is farming done by agency staff and equipment? ( ) Yes ( ) No
   2. Is farming done by contract? ( ) Yes ( ) No
   3. What are crops grown? __________ __________ __________ __________
   4. Are crops rotated periodically? ( ) Yes ( ) No
   5. Are soils tested to check nutrient balances? ( ) Yes ( ) No
   6. Is fertilizer added? __________ If so, what type ____________________ How much ____________________

F. Overall
   1. Is a preventive maintenance plan in use? ( ) Yes ( ) No
   2. Is there a safety program? ( ) Yes ( ) No
   3. Is there an emergency plan for power outages or major equipment failure? ( ) Yes ( ) No
   4. Does the sampling program meet recommendations? ( ) Yes ( ) No
   5. Is an O&M manual available? ( ) Yes ( ) No
   6. Is O&M manual used? ( ) Yes ( ) No
   7. Is laboratory properly equipped? ( ) Yes ( ) No
   8. What spare parts are stocked? ____
   ____
   ____
   9. What are the most common problems the operator has had with the process?____
   ____
   ____
   ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

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24. FLOW MEASUREMENT

Process Description

Flow measurement is necessary for good operation and control of a wastewater treatment plant. Reasons for measuring flow of wastewater include:

1. To provide operating and performance data concerning the treatment plant.
2. To compute costs of treatment, where such costs are based on wastewater volume.
3. To obtain data for long term planning of treatment plant capacity versus actual capacity used.

There are many methods of measuring flow, some for open channel flows and others to measure flow in pipelines. The most commonly used flow measurement devices are the propeller meter, the magnetic flow meter, the Venturi tube, the positive displacement diaphragm meter, weirs, the Parshall flume, the parabolic nozzle and the rotameter.

Typical Performance Evaluation

Since flow measuring devices are not for treating wastewater, this section deals with performance in terms of accuracy of measurement. The normal accuracy for each meter previously described is shown below:

Type of flow meter	% Accuracy
Propeller meter	±2% of actual flow rate over a range of 7:1 for small meters and up to 12:1 for large meters
Magnetic meter	
Below 3 fps	±2% of maximum scale reading
3 - 30 fps	±1% of maximum scale reading
Venturi tube	±3 to 4% of flow rate
Flow tube	±1% of flow rate
Positive displacement and diaphragm meter	±1% of flow rate
Weirs	±5% of flow rate
Parshall flume	±5% of flow rate
Kennison or parabolic nozzle	±2% of flow rate over flow range of 10:1
Rotameter	±2% of maximum scale

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are:

1. A thorough periodic inspection of the flow measuring device.
2. Floats and bubbler wells regularly checked for grease or debris build up.
3. Weir plates regularly cleaned of foreign matter.
4. Regular schedule for calibration of the flow meter.
5. Recording devices properly maintained.

Records

Records should be kept for flows on a daily basis. Many devices produce a continuous flow chart for plant records. Flow records should contain date, flow, time of reading and operator's name, if applicable. Inspection dates and calibration data should also be recorded.

Process Checklist - Flow Measurement

1. What type of flow meter is used ______________________________?
2. What is the wastewater flow ______________mgd?
3. What is the design flow ____________________mgd?
4. Frequency of routine inspection for proper operation _______________/day?
5. Frequency of maintenance inspections by plant personnel ____________/yr?
6. Frequency of flow meter calibration _______________/month?
7. Is maintenace program adequate? ( ) Yes ( ) No
8. Are floats and bubbler wells clean and free of grease of debris?
   ( ) Yes ( ) No
9. Are weirs free of debris? ( ) Yes ( ) No
10. Are flow records properly kept? ( ) Yes ( ) No
11. Are sharp drops or increases in flow records accounted for?
    ( ) Yes ( ) No
12. Does the flow chart exhibit uniform flow? ( ) Yes ( ) No
13. Do any plant return flows discharge upstream from the meter?
    ( ) Yes ( ) No
14. Are recording devices properly maintained? ( ) Yes ( ) No
15. Does the meter show signs of oveload? ( ) Yes ( ) No
16. Are spare parts stocked, if applicable? ( ) Yes ( ) No
17. What are the most common problems that the operator has had with the flow meter? ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. State of Virginia O&M inspection form.

25. SLUDGE PUMPING

Process Description

Sludge pumps have many uses in a municipal wastewater treatment plant. Settled primary sludge must be moved regularly; activated sludge must be returned continuously to aeration tanks, with the excess sludge wasted; scum must be pumped to digestion tanks; and sludge must be recirculated and transferred within the plant in processes such as digestion, trickling filter operation, and final disposal. The type of pumping station used at the plant depends on the characteristics of the sludge itself.

Pumps used for handling sludges may be centrifugal, air lift and ejectors, grinding, Archimedes screw lift, and positive displacement types.

Typical Performance Evaluation

Below is a listing of various types of sludge pumps, their capacities, and delivered pressure. This table may be used as a general guide to evaluating the performance of sludge pumps at a treatment plant. For a very precise evaluation, the actual operating characteristics of the pump should be checked against manufacturers' design data for the pump. Pumps cannot be expected to operate beyond their designed capacity.

Type of pump	Capacity (gpm)	Delivered pressure (psi)
Plunger pump	up to 500	100 - 150
Rotary positive displacement (progressing cavity pump)	up to 400	up to 500
Diaphragm	up to 100	up to 100
Sludge grinding pumps (comminuting and pumping type)	25 - 300	- -
Screw lift pump	up to 80,000	- -

Process Control

To be effective, sludge pumping systems must be flexible under different plant operating conditions. The overall piping, valves, and pumping system must be set up to allow bypassing and provide standby pumping capacity when problems occur.

The most important control considerations are discussed in Reference 1.

Maintenance Considerations

See Raw Sewage Pumping Stations and General Maintenance Management.

Records

Recommended records include:

1. Amount of sludge and scum pumped per day.
2. Frequency and duration of operation of sludge pumps.
3. Maintenance charts including date, type of work and operator.
4. Inspection records including date, type of inspection and operator.

Process Checklist - Sludge Pumping

1. What is the volume of sludge pumped ___________gal/day?
2. What types of sludge are pumped? _________________________
3. What is the design sludge pumping rate __________gal/day?
4. Is sludge pumping ( ) manual ( ) automatic?
5. How often do sludge pumps run? _______________________________
6. Frequency of maintenance inspections by plant personnel ______________year?
7. Is maintenance program adequate? ( ) Yes ( ) No
8. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
9. Are operating records adequate? ( ) Yes ( ) No
10. What spare parts are stocked? ____ ____
11. What are the most common problems the operator has had with the system? ____ ____ ____ ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

26. CHEMICAL CONDITIONING

Process Description

The most frequently encountered conditioning practice is the use of ferric chloride either alone or in combination with lime, although the use of polymers is rapidly gaining widespread acceptance. Ferric chloride and lime are normally used in combination, although it is not unusual for them to be applied individually. Lime alone is a fairly popular conditioner for raw primary sludge and ferric chloride alone has been used for conditioning activated sludges. Lime treatment to a pH of 10.4 or above has the added advantage of providing a significant degree (over 99 percent) of disinfection of the sludge according to "Water Supply and Treatment", Bulletin 211, published by the National Lime Association.

The popularity of polymers is primarily due to their ease in handling, small storage space requirements, and their effectiveness. All of the inorganic coagulants are difficult to handle and their corrosive nature can cause maintenance problems in the storing, handling, and feeding systems in addition to the safety hazards inherent in their handling. Many plants in the U.S. have abandoned the use of inorganic coagulants in favor of polymers.

The facilities for chemical conditioning are relatively simple and consist of equipment to store the chemical(s), feed the chemical(s) at controlled dosages, place the chemical(s) in solution or slurry, and feed the solution to the process.

The equipment used for storing and handling these chemicals varies with the type of chemical used, liquid or dry form of the chemical, quantity of chemical used, and plant size. Storage requirements vary, but typically may be 15 to 30 days of use or 150 percent of the bulk transport capacity, whichever is greater.

Typical Design Considerations

Feed rates for chemical conditioning of sludges are extremely variable depending on process used, nature of the sludge, and type of chemical. Typical range of dosages are as follows:

	$FeCl_3$, lb/solids	Lime, lb CaO/solids	Polymer, solids
Raw primary + waste activated sludge	40-50	110-300	15-20
Digested primary + waste activated sludge	80-100	160-370	30-40
Elutriated primary + waste activated sludge*	40-125	-	20-30

*Elutriated sludge results from a process whereby the sludge is washed with either fresh water or plant effluent to reduce the demand for conditioning chemicals and to improve settling of filtering characteristics.

Typical Performance Evaluation

The primary benefits of chemical conditioning of sludge are improved dewatering and thickening characteristics and higher loading rates and more effective solids capture in subsequent unit processes. Because of vast differences in sludge characteristics, typical performance data varies widely from plant to plant.

Process Control

If the feeders are automatically paced to flow, feed rate adjustments are required only to compensate for varying dosage requirements. If the feeder is not paced to flow the feed rate must be adjusted each time the plant flow rate is changed. The lime slaker requires occasional adjustment for variations in lime quality.

Maintenance Considerations

Proper and regular maintenance of the chemical feed system is critical to the efficient and troublefree operation of the system. The features of a maintenance program that should insure these conditions are listed below.

1. Spare parts inventory should include at least one set of each type of bearing, grease and water seals, one each of all gaskets, drive belts, isolation pads and springs, one feed pump head.
2. Build-up or spilling of material (chemicals) regularly cleaned off.
3. Visual inspection each shift of the chemical feeding equipment to check for excessive noise, unequal loading if there is more than one metering pump, chemical leakage, damage to storage tanks, raw materials, mixing tanks or metering pumps.
4. Records to determine the dose rate to the wastewater and also evaluate whether or not this value is changing with time. If the wastewater characteristics remain the same, changing dosages could indicate a problem with the chemical feed equipment.
5. Storage bins and conveyance systems checked regularly to insure air-tightness.
6. Check the calibration of the pH probe each shift to insure the automatic control system is operating correctly.
7. Daily inspection to check for plugged feed lines.
8. All chemical feed lines whether suction, discharge or lines conveying solid or powered materials, flushed or blown out regularly to insure against plugging and solids build-up.

Records

The chemical dosage required for any sludge is determined in the laboratory using the Buchner Funnel test, filter leaf test, or jar test. Operating records should include:

1. Type of chemical used for conditioning.
2. Chemical dosage applied each day.
3. Type of sludge conditioned.
4. Sludge quantity conditioned each day.
5. Frequency and duration of operation of feed equipment or pumps.
6. Maintenance charts including date, type of work, and operator.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor chemical sludge conditioning:

1. Analytical balance
2. Floc stirrer
3. Buchner funnel

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples used to determine the chemical dosage required for any sludge should be collected from valves provided in the sludge transfer piping. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used.

Sidestreams

The only sidestream from sludge conditioning is the dust associated with the handling of bulk quantities of dry chemicals. To control dust problems, vapor and dust collection systems are often used.

Process Checklist - Chemical Conditioning

1. What is the volume of sludge conditioned ____________gallons/day average?
2. What is the design sludge volume ____________gallons/day average?
3. What type of sludge is conditioned (primary, waste activated, combination, other, etc.) ________________________?
4. What type of chemical is used for conditioning (lime, ferric chloride, combination, polymer, etc.) ________________?
5. What is the chemical dosage ____________ lb/ton dry solids average?
6. Are chemicals purchased dry ______ or as a liquid________?
7. What chemical storage volume is provided ____________days?
8. Is chemical feed system ( ) automatic ( ) manual?
9. If dry feeders are used, are the feeders ( ) volumetric or ( ) gravimetric?
10. Are chemical feeders automatically paced? ( ) Yes ( ) No
11. If lime is used, is lime purchased ( ) in bags ( ) bulk quantities?
12. If lime feeding is used, is a vapor and dust collection system installed? ( ) Yes ( ) No. Operating? ( ) Yes ( ) No
13. Does the unit show signs of inadequate mixing? ( ) Yes ( ) No
14. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
15. Are operating records adequate? ( ) Yes ( ) No
16. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
17. What spare parts are stocked? ______________________________
____
____
____
18. What are the most common problems the operator has had with the process?
____
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. National Lime Association, Lime Handling, Application, and Storage, Washington, D.C. 20016.

7. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

27. THERMAL TREATMENT

Process Description

There are two basic processes for thermal treatment of sludges. One, wet air oxidation, is the flameless oxidation of sludges at temperatures of 450 to 550°F and pressures of about 1200 psig. The other type, heat treatment, is similar, but carried out at temperatures of 350 to 400°F and pressures of 150 to 300 psig. Wet air oxidation reduces the sludge to an ash and heat treatment improves the dewaterability of the sludge. The lower temperature and pressure heat treatment is more widely used than the oxidation process.

Thermal treatment systems release water that is bound within the cell structure of the sludge and improves the dewatering and thickening characteristics of the sludge. The oxidation process further reduces the sludge to ash by wet incineration (oxidation). The process also provides effective disinfection of the sludge.

Typical Design Considerations

The most important parameter is the influent sludge flow rate (gpm). The flow rate determines the detention time in the heat exchanger(s) which is typically 30 to 60 minutes.

The influent solids concentration is also an important parameter. Many plants operating in the 350-400°F range use a 3 percent sludge, however, 6 percent is more desirable because less steam is needed. An example calculation for percent solids is shown below:

$$\text{Percent solids concentration} = \frac{\text{weight of dry sludge}}{\text{weight of wet sludge}} \times 100$$
$$= \frac{0.6\text{ lb}}{10\text{ lb}} \times 100 = 6\%$$

Typical Performance Evaluation

The reduction in chemical oxygen demand (COD) of the sludge depends on the degree of wet oxidation achieved by the process. The terms used to categorize the degree of wet oxidation - low oxidation, intermediate oxidation, and high oxidation - refer to the degree of reduction in the chemical oxidation demand (COD) of the sludge. Higher temperatures are required to effect higher degrees of oxidation, and the higher temperatures, in turn, require the use of correspondingly higher pressures in order to prevent flashing to steam or burning.

The operating temperature, pressure ranges, and COD reduction for the three oxidation categories are given below:

Oxidation category	COD reduction, %	Temp., °F	Pressure, psi
Low	5	350-400	300-500
Intermediate	40	450	750
High	92-98	675	1,650

Process Control

The extent and rate of sludge solids oxidation are determined by the reactor pressure and temperature. These and other process control considerations are discussed in Reference 7.

Maintenance Considerations

The features of a good maintenance program for both components and system are shown below:

1. Schedule for periodic cleaning of the heat treatment system.
2. Routine cleaning procedures available for the heat exchanger, the reactor, and the oxidized sludge decant tank.
3. Inspection schedule for piping to determine when a solvent wash is necessary.
4. Instructions to the operator to indicate if cleaning is necessary before the scheduled time period. For example, the need for heat exchanger cleaning is indicated by an increasing temperature differential between the reactor inlet and outlet, and an increasing pressure drop through the system.
5. Provisions for a thorough check for scale buildup inside the reactor on an annual basis to determine if acid cleaning procedures are ineffective.
6. Provisions for mechanical removal of the scale if acid cleaning procedures are ineffective in the reactor.
7. Annual pressure check to insure the integrity of the pressure piping and fittings.

Records

Recommended sampling and laboratory tests are shown in Figure 27-1.

Other operating records should include:

1. Influent sludge flow
2. Treated sludge flow
3. Frequency and duration of system operation.
4. COD of oxidized sludge decant.

Laboratory Equipment

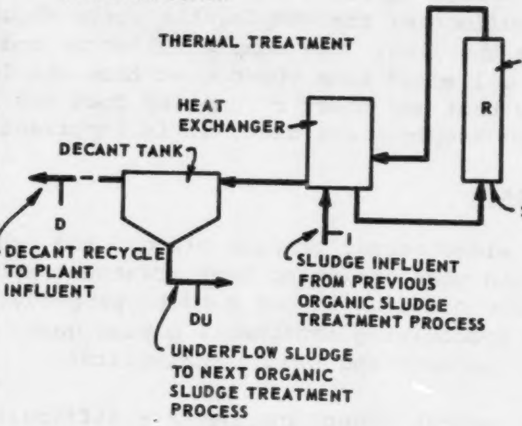
The laboratory should include the following minimum equipment in order to monitor thermal treatment:

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SOLIDS REDUCTION

THERMAL TREATMENT

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TOTAL SOLIDS	ALL	1/D	I DU	G	P
	TEMPERATURE	ALL	Mn	R	Mn	P
	pH	ALL	1/D	D	G	H
	SUSPENDED SOLIDS	ALL	1/D	D	G	H
	BOD	ALL	2/W	D	G	P[1]
	FLOW	ALL	R	D	R	P[1]
OPTIONAL						


REACTOR
R
HEAT EXCHANGER
DECANT TANK
D
STEAM
I
DECANT RECYCLE TO PLANT INFLUENT
SLUDGE INFLUENT FROM PREVIOUS ORGANIC SLUDGE TREATMENT PROCESS
DU
UNDERFLOW SLUDGE TO NEXT ORGANIC SLUDGE TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
D = DECANT
R = REACTOR (INCLUDE AS PROCESS TESTING)
DU = DECANT UNDERFLOW

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 27-1

1. Analytical balance
2. pH meter
3. BOD incubator
4. Drying oven
5. COD apparatus

Sampling Procedures

The system should contain sample ports to aid in the collection process. Before collecting the sample, the ports should be opened for several seconds to purge the line. The sample collector and containers should be clean. Samples collected from the decant tank should be taken near the discharge point so that any short circuiting does not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

Two sidestreams, process off-gas and recycle liquor, require careful consideration when operating heat treatment systems. The system off-gas can cause odor problems if not handled properly. Treatment may include installation of deodorizing equipment, piping gases back to diffused system or piping gases to an existing sludge incinerator.

The recycle liquor can be very difficult to treat, offensive smelling, and can upset plant treatment processes. Typical recycle liquor characteristics are as follows.

Substances in strong liquor	Concentration range, mg/l (except as shown)
TSS	100 - 20,000
COD	100 - 17,000
BOD	3,000 - 15,000
NH_3-N	400 - 1,700
Phosphorus	20 - 150
Color	1,000 - 6,000 units

These high concentrations illustrate the potential impact that recycle of the liquor can have on the wastewater treatment processes. It is important to recognize the significance of the recycle load in the management of the overall plant operation.

Process Checklist - Thermal Treatment

1. What is the influent sludge flow ____________gpm? What is the operating temperature __________°F? What is the operating pressure ______lb/sq in?
2. What is the design sludge flow ____________gpm? What is the design temperature __________°F? What is the design pressure ______lb/sq in?
3. What is the influent sludge solids concentration ______________%?
4. What is the volume of the treated sludge __________________gal/day?
5. What is the recycle liquor flow ____________gal/day?
6. What is the solids concentration of the treated sludge ________________%?
7. What is the BOD of the recycle liquor ______________mg/l?
8. What is the COD of the recycle liquor ______________mg/l?
9. What is the suspended solids concentration of the recycle liquor? ________
10. How is the recycle or decant liquor treated ____________________________?
11. Does treatment of the recycle liquor upset the plant? ( ) Yes ( ) No
12. How are the off-gases handled ____________________________?
13. Are excessive odors present from off-gases? ( ) Yes ( ) No
14. What is the duration and frequency of system operation ____________hr/day?
15. Frequency of acid wash ____________/year
16. Frequency of general maintenance inspections ____________/year?
17. Frequency of scale buildup inspection: Heat exchanger ____________/year Reactor ____________/year, Piping ____________/year, Oxidized sludge decant tank __________________/year, Other component ______________ ________________/year
18. Frequency of system pressure check to insure integrity of pressure piping and fittings __________________/year
19. Is the maintenance program adequate? ( ) Yes ( ) No
20. If multiple units are used, is the flow distributed evenly? ( ) Yes ( ) No
21. Are proper safety precautions used for handling acid? ( ) Yes ( ) No; Electrical ( ) Yes ( ) No; Exposure to gases ( ) Yes ( ) No; High temperatures ( ) Yes ( ) No; High pressures ( ) Yes ( ) No; Mechanical equipment ( ) Yes ( ) No
22. Are State and Federal safety codes followed? ( ) Yes ( ) No
23. Does the unit show signs of overload? ( ) Yes ( ) No
24. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
25. Does the sampling program meet the recommendations? ( ) Yes ( ) No
26. Are operating records adequate? ( ) Yes ( ) No
27. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
28. What spare parts are stocked? ____
    ____
    ____
29. What are the most common problems the operator has had with the process?
    ____
    ____
    ____
    ____

References

1. Culp. G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Culp/Wesner/Culp Operation and Maintenance Manual, Water Factory 21, Orange County Water District, (June, 1974).

6. Culp, R.L., et al, Effects of Thermal Treatment of Sludge on Municipal Wastewater Treatment Costs EPA Contract 68-03-2186.

7. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

28. GRAVITY THICKENING

Process Description

Gravity thickening is the most common sludge concentration process used in the United States. Gravity thickening is a sedimentation process similar to primary and secondary sedimentation. The objective of sludge thickening is to produce as thick a sludge as possible at minimum cost. Chemicals may be used to aid the gravity thickening process.

Solids settle by gravity to the bottom of the basin forming a sludge blanket with a clearer liquid (supernatant) above. The supernatant is removed from the basin over weirs located near the top of the tank at the outside edge. Thickening takes place as the sludge particles move to the bottom of the tank and the water moves toward the top. As the drive unit turns the mechanism the blanket is gently stirred, which helps compact the sludge solids and release water from the mass. Sludge solids are scraped toward a center well and withdrawn.

Typical Design Considerations

Gravity thickeners are designed based on surface overflow rate (hydraulic loading) and solids loadings. The principles that apply are the same as those used in designing sedimentation tanks. Typically, a proposed design is checked for both overflow rate and solids loading and the final selection is based on a thickener design that will meet both of the design considerations.

The surface overflow rate is expressed in terms of gallons per day per square foot of surface area of the tank. The overflow rate is calculated as shown in the following example.

1. Determine thickener shape and dimensions. The plant construction drawings and specifications include this information.
   Shape = circular
   Diameter, dia = 30 ft
   Depth, D = 10 ft
   Thickener area, $A = (\pi/4)\text{dia}^2$ = 707 sq ft
2. Determine total sludge flow influent to thickener and influent sludge and thickened sludge solids concentrations and calculate total overflow volume.
   Influent flow = 700,000 gallons per day (gpd)
   Influent solids, % = 5
   Thickened solids, % = 10

   $$\text{Overflow volume} = \text{Influent flow}\left(1 - \frac{\text{Influent solids}}{\text{Thickened solids}}\right)$$
   $$= 700,000\,(1 - 5/10)$$
   $$= 350,000 \text{ gpd}$$
3. Calculate surface overflow rate for thickener.

   $$\text{Overflow rate} = \frac{\text{flow in gal/day}}{\text{surface area in sq ft}}$$
   $$= \frac{350,000}{707}$$
   $$= 495 \text{ gpd/sq ft}$$

The solids loading rate is expressed in terms of pounds per day of solids per square foot of surface area of the tank. The solids loading rate is calculated as shown in the following example.

1. Thickener area = 500 sq ft
2. Determine total pounds per day of solids applied to the thickener.
   Sludge flow = 30,000 gpd
   Solids concentration = 1.0 percent solids
   Total solids, lb/day = 30,000 gal/day x 8.34 lb/gal x 0.01
   = 2,502 lb/day
3. Calculate solids loading rate for thickener.

$$\text{Solids loading rate} = \frac{2{,}502\ \text{lb/day}}{500\ \text{sq ft}} = 5.0\ \text{lb/sq ft/day}$$

Current practice in the United States calls for design overflow rates of 400 to 800 gpd per square foot. The design solids loadings will vary with the type of sludge and typical loadings are shown in Table 28-1. This table was developed from information in "Process Design Manual for Sludge Treatment and Disposal", EPA 625/1-74-006, October, 1974.

TABLE 28-1. GRAVITY THICKENER TYPICAL LOADINGS AND PERFORMANCE

Sludge type	Influent solids concentration, percent	Typical solids loading rate, lb/sq ft/day	Thickened sludge concentration, percent
Raw primary	5.0	20-30	8.0-10
Raw primary + $FeCl_3$	2.0	6	4.0
Raw primary + low lime	5.0	20	7.0
Raw primary + high lime	7.5	25	12.0
Raw primary + WAS*	2.0	6-10	4.0
Raw primary + (WAS + $FeCl_3$)	1.5	6	3.0
(Raw primary + $FeCl_3$) + WAS	1.8	6	3.6
Digested primary	8.0	25	12.0
Digested primary + WAS	4.0	15	8.0
Digested primary + (WAS + $FeCl_3$)	4.0	15	6.0
WAS	1.0	5-6	2-3
Trickling filter	1.0	8-10	7-0

*WAS = Waste activated sludge

Typical Performance Evaluation

Expected thickener performance, in terms of thickened sludge concentration, is also given in Table 28-1. Gravity thickening should remove 90 percent of the solids in the feed to the thickener as an average.

Process Control

Typically the flow through the thickener is continuous and should be set for as constant a rate as possible.

The drive mechanism normally turns continuously and contains a torque monitor which will shut down the drive and sound an alarm if the drive mechanism is overloaded.

A review of Table 28-2 will show that for many sludges the thickened sludge is only 2 or 3 times the concentration of the influent sludge. In order to maintain the thickener solids balance, the thickened sludge flow rate for these cases must be 30 to 50 percent of the influent flow. In most cases it will be advantageous to draw off thickened sludge continuously at a flow rate approximately equal to:

$$\text{Thickened sludge flow rate, gpm} = \text{Influent flow, gpm} \times \frac{\text{Influent solids, \%}}{\text{Thickened solids, \%}}$$

It is important to maintain an adequate thickened sludge flow rate or sludge will accumulate very rapidly in the thickener.

Maintenance Considerations

The features of a good maintenance program are the same as Sedimentation Maintenance and as described for General Maintenance Management.

Records

Recommended sampling and laboratory tests are shown in Figure 28-1.

Other operating records should include:

1. Amount of sludge and scum pumped per day.
2. Amount of thickened sludge pumped per day.
3. Frequency and duration of operation of sludge pumps.

Laboratory Equipment

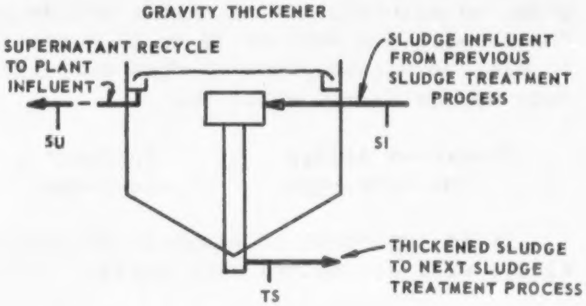
The laboratory should include the following minimum equipment in order to monitor gravity thickening:

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Imhoff Cones

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SLUDGE CONCENTRATION


GRAVITY THICKENER
SUPERNATANT RECYCLE TO PLANT INFLUENT
SLUDGE INFLUENT FROM PREVIOUS SLUDGE TREATMENT PROCESS
SU
SI
THICKENED SLUDGE TO NEXT SLUDGE TREATMENT PROCESS
TS

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	1/D	TS SI	G	P C
SUSPENDED SOLIDS	ALL	1/D	SU	G	P
BOD	ALL	2/W	SU	G	P[1]
FLOW	ALL	R	SU	R	P[1]

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

SI = SLUDGE INFLUENT
TS = THICKENED SLUDGE
SU = SUPERNATANT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 28-1

Sampling Procedures

Sampling should be performed as outlined under Records. These samples may be obtained through valves provided in the respective thickener piping. If sampling points are not provided, they should be installed to facilitiate operation and control of the process. Samples of the supernatant can be obtained at the overflow weir. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Sidestreams

The only sidestream from the gravity thickening process is the thickener supernatant. Thickener supernatant is usually returned to either the primary or the secondary treatment process and normally causes no problem to process operation. The respective treatment process must be sized to treat the supernatant flow and organic loading in addition to normal plant flow.

Process Checklist - Gravity Thickening

1. What type of sludges are fed to the thickener (primary, waste activated, combination, etc.) ______________________________?
2. What is the volume of influent sludge flow ______________gal/day avg?
3. What is the design influent flow ______________________gal/day avg?
4. What are the dimensions of the thickener __________________?
5. How much thickened sludge is pumped ____________________gal/day avg?
6. What is the solids concentration in the influent sludge ___________%?
7. What is the solids loading rate __________________ pounds/day/sq ft?
8. What is the solids concentration in the thickened sludge __________%?
9. What is the settleable solids concentration in the supernatant ____________ ml/l?
10. Is influent sludge feeding intermittent or continuous __________________?
11. Is thickened sludge pumping ( ) manual ( ) automatic?
12. How often do thickened sludge pumps run _____________ minutes/hour?
13. Frequency of maintenance inspections by plant personnel ______/year?
14. Is maintenance program adequate? ( ) Yes ( ) No
15. How much downtime is there ______________days/year?
16. What is the frequency of cleaning ___________/year?
17. Does the influent baffle system accomplish its purpose? ( ) Yes ( ) No
18. Is the sludge collection system operating properly? ( ) Yes ( ) No
19. Does the sludge collection system show any signs of mechanical failure? ( ) Yes ( ) No
20. Does the tank surface indicate improper sludge withdrawal? (i.e. excessive floating solids, gas. . .)
21. Does the effluent baffle system accomplish its purpose? ( ) Yes ( ) No
22. Are the effluent weirs level? ( ) Yes ( ) No
23. Are surfaces and the effluent weirs kept clean? ( ) Yes ( ) No
24. If multiple units are used, is the flow distributed evenly? ( ) Yes ( ) No
25. Does the unit show signs of short circuiting and/or overloads? ( ) Yes ( ) No
26. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
27. Does the sampling program meet the recommendations? ( ) Yes ( ) No
28. Are operating records adequate? ( ) Yes ( ) No
29. Is the laboratory equipped for the necessary analyses? ( ) Yes ( )No
30. What spare parts are stocked? ______________________________
____
____
____
31. What are the most common problems the operator has had with the process?
____
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

29. FLOTATION THICKENING

Process Description

Sludge thickening by flotation is a process effective for light sludges. This process causes the sludge to float so it can be skimmed from the surface of the thickener. Flotation is especially effective on activated sludge which is difficult to thicken by gravity because of its low specific gravity. Air is injected into the incoming sludge under pressure. The sludge then flows into an open tank where, at atmospheric pressure, much of the air comes out of solution as minute air bubbles. These bubbles attach to sludge particles, floating them to the surface. A sludge layer 8 to 24 inches thick forms on the surface of the tank and can be removed by a skimming mechanism for further processing. Flotation aids such as polymers can be used to increase performance. If polymer is used the optimal chemical dosage for the feed sludge should be determined at the start of each shift using jar test procedures.

Typical Design Considerations

Flotation thickeners are typically designed based on solids loading, overflow rate, and influent solids concentration. Typical design and operating parameters are given in Table 29-1.

The solids loading rate is expressed in terms of pounds per hour of dry solids per square foot of surface area of the tank. The solids loading rate is calculated in the following example.

1. Determine the surface area of flotation thickener. The plant construction drawings and specifications should include this information.
   Area = 168 sq ft

2. Determine total pounds per day of solids applied to the thickener.
   Sludge flow = 150,000 gallons/day
   Sludge concentration = 1.0 percent solids
   $$\text{Total solids, lb/day} = 150{,}000\ \frac{\text{gal}}{\text{day}} \times 8.34\ \frac{\text{lb}}{\text{gal}} \times 0.01 = 12{,}510\ \text{lb/day}$$

3. Calculate solids loading rate for thickener.
   Total solids = 12,510 lb/day x 1 day/24 hours = 521 lb/hour
   $$\text{Solids loading rate} = \frac{521\ \text{lb/hr}}{168\ \text{sq ft}} = 3.1\ \text{lb/sq ft/hour}$$

Solids loading often is designed at 2 lb/hr/sq ft. This rate is possible using flotation aids, with or without auxiliary recycle. Many flotation thickeners are operated at 3.0 lb/hr/sq ft, although built-in capacities of 4.0-5.0 lb/hr/sq ft are common and provide flexibility in operation. There are times when flotation can be done without flotation aids, and auxiliary recycle is used instead. Without flotation aids, loading rates are about 50 percent and solids removal may be less.

TABLE 29-1. FLOTATION THICKENER OPERATION AND PERFORMANCE

Operation parameter	Range	Typical
Solids loading, lb dry solids/hr/sq ft of surface		
With chemicals	2 to 5	2
Without chemicals	1 to 2	1
Influent solids concentration, mg/l	5,000 min	5,000 min
Air to solids ratio	0.02-0.04	0.03
Blanket thickenss, in	8-24	-
Retention tank pressure, psi	60-70	-
Recycle ration, % of influent flow	30-150	
Expected Performance		
Float solids concentration, %		3-7
Solids removal, %		
With flotation aid		95
Without flotation aid		50-80

Typical maximum hydraulic loading or overflow rate is 0.80 gpm/sq ft at minimum solids concentration of 5,000 mg/l. Lower solids levels or higher hydraulic loadings result in lower efficiencies and/or float solids concentrations.

Another operating parameter included in Table 29-1 is the air to solids ratio. The air to solids ratio is the ratio of air feed to dry sludge solids feed by weight. The weight of air is 0.08 times the flow rate in standard cu ft per min.

$$\text{Ratio} = \frac{(0.08)\ (\text{Air flow, cfm})}{\text{Influent dry solids, lb}}$$

Typical Performance Evaluation

Expected thickener performance, in terms of typical float solids concentration and percent solids removal, is shown in Table 29-1.

A 4 percent minimum float solids concentration by weight is normally used for design purposes. However, a 5-6 percent float solids concentration can be expected. Flotation without chemical aids usually results in a solids concentration that is about 1 percent less than with flotation aids. Using flotation, at least 95 percent of suspended solids can be removed with flotation aids, and 50-80 percent without flotation aids.

Process Control

Typically the flow through the thickener is continuous and should be set for as constant a rate as possible. Process controls are discussed in some detail in References 1 and 6.

Maintenance Management

The features of a good maintenance program are:

1. Major elements been inspected semi-annually for wear corrosion, and proper adjustment.
    a) Drives and gear reducers
    b) Chains and sprockets
    c) Guide rails
    d) Shaft bearings and bores
    e) Bearing brackets
    f) Baffle boards
    g) Flights and skimming units

2. Mechanical check made on the following units at two hour intervals.
    a) Pumps: chemical feed, recycle, reaeration, and sludge sumps
    b) Air manometer operation
    c) Retention tank pressure
    d) Sludge pit mixers

3. Retention tank inspected on a regular basis for excessive corrosion.

4. Chain tension (in rectangular basins) been adjusted properly so that there is no chattering sound.

5. Spare part inventory should contain the following: flights and drive chains for rectangular basins, turntable gears and motors for circular basins, wear shoes, sprockets, wall brackets, chain pins, and shear pins.

Records

Recommended sampling and laboratory tests are shown in Figure 29-1.

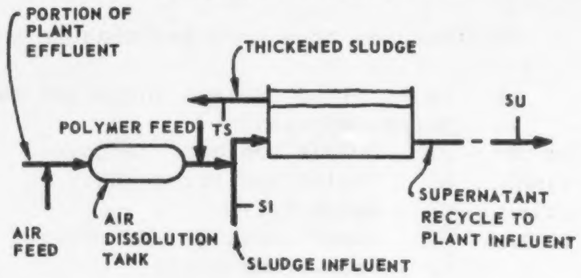
Other operating records should include:

1. Amount of recycle flow pumped per day.
2. Amount of thickened sludge pumped per day.
3. Frequency and duration of operation of sludge pumps.
4. Amount of polymer or other flotation aid fed each day.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SLUDGE CONCENTRATION

AIR FLOTATION THICKENING


PORTION OF PLANT EFFLUENT
THICKENED SLUDGE
SU
POLYMER FEED
TS
SI
AIR FEED
AIR DISSOLUTION TANK
SLUDGE INFLUENT
SUPERNATANT RECYCLE TO PLANT INFLUENT

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TOTAL SOLIDS	ALL	1/D	TS SI	G	P C
	BOD	ALL	2/W	SU	G	P^1
	SUSPENDED SOLIDS	ALL	1/D	SU	G	P
	FLOW	ALL	R	SU	R	P^1
OPTIONAL						

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

SI = SLUDGE INFLUENT
TS = THICKENED SLUDGE
SU = SUBNATANT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. FOR CONTROL OF PROCESS RECEIVING THIS FLOW.

Figure 29-1

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor flotation thickening.

1. Analytical balance
2. BOD incubator
3. Drying oven

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Sampling should be performed as outlined under Records. These samples may be obtained through valves provided in the respective thickener piping. If sampling points are not provided, they should be installed to facilitate operation and control of the process. Samples of the supernatant can be obtained at the overflow weir.

The sample collector and containers should be clean. A wide mouth, sample collector of at least 2 inches should be used. Samples should be analyzed according to procedures specified in Standard Methods and, in addition, should be visually analyzed.

Sidestreams

The only sidestream from flotation thickening process is the thickener subnatant. A portion of the subnatant flow is recycled back to the flotation unit, while the remainder is usually returned to either the primary or the secondary treatment process.

Process Checklist - Flotation Thickening

1. How many air flotation thickening units are there ____________?
2. What are the dimensions of the thickener(s) __________________?
3. Are the flotation tanks ( ) circular ( ) rectangular?
4. What type of sludge is fed to the thickener (waste activated, other biological, etc.) ______________________________________?
5. What is the volume of influent sludge flow ___________________gal/day avg?
6. What is the design influent flow _____________________________gal/day avg?
7. How much thickened sludge is pumped ___________________gallons/day?
8. What is the solids concentration in the influent sludge ______________?
9. What is the solids loading rate ____________________lb/hour/sq ft?
10. What is the air to solids ratio ____________________?
11. What is the hydraulic loading or overflow rate ______________gpm/sq ft?
12. What is the solids concentration in the thickened sludge ___________%?
13. What is the suspended solids concentration in the subnatant __________mg/l?
14. What is the solids removal efficiency ______________%?
15. Are flotation aids used? ( ) Yes ( ) No. What type ________________?
16. What is the average dosage of flotation aid ______________lb/ton dry solids
17. What is the thickness of the floating sludge blanket ______________inches?
18. Is influent sludge feeding ( ) intermittent ( ) continuous?
19. What is the effluent recycle ratio (percent of influent flow) _________?
20. Are primary and secondary effluent readily available for auxiliary recycle? ( ) Yes ( ) No
21. Is thickened sludge pumping ( ) manual ( ) automatic?
22. How often do thickened sludge pumps run ______________minutes/hour?
23. Frequency of maintenance inspections by plant personnel _____________/year?
24. Is maintenance program adequate? ( ) Yes ( ) No
25. How much down time is there ___________________days/year?
26. What is the frequency of cleaning ________________/year?
27. Does the influent baffle system accomplish its purpose? ( ) Yes ( ) No
28. Is the skimmer blade sludge removal system operating properly? ( ) Yes ( ) No
29. Is the bottom sludge collection system operating properly? ( ) Yes ( ) No
30. Does the sludge collection system show any signs of mechanical failure? ( ) Yes ( ) No
31. Does the effluent baffle system accomplish its purpose? ( ) Yes ( ) No
32. Are the effluent weirs level? ( ) Yes ( ) No
33. Are surfaces and the effluent weirs kept clean? ( ) Yes ( ) No
34. If multiple units are used, is the flow distributed evenly? ( ) Yes ( ) No
35. Does the unit show signs of short circuiting and/or overloads? ( ) Yes ( ) No
36. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
37. Does the sampling program meet the recommendations? ( ) Yes ( ) No
38. Are operating records adequate? ( ) Yes ( ) No
39. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No

40. What spare parts are stocked? ______________________________

____

41. What are the most common problems the operator has had with the process?

____

____

____

____

____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-001.

7. Harrison, J.R., Goodson, J.B., and Culp, G.L., Process Design Manual for Sludge Treatment and Disposal, US EPA 625/1-74/006.

30. ANAEROBIC DIGESTION

Process Description

EPA has published "Operations Manual - Anaerobic Sludge Digestion" (EPA 430/9-76-001) which provides very detailed information on the process and troubleshooting. This manual should be read for more complete information than given here. In anaerobic digestion, the organic matter in the sludge is broken down without oxygen. In low rate digestion, one digester is used. Fresh sludge is fed into it two or three times daily. As decomposition occurs, three separate layers form. A scum layer is formed at the top of the digester, and below it are supernatant and sludge layers. The sludge zone has an actively decomposing upper layer and a relatively stabilized bottom layer. The stabilized sludge settles at the base of the digester and supernatant is usually returned to the plant influent. Most modern systems are "high rate" systems utilizing one or two stages. The sludge stabilizes in the first stage, while the second stage provides settling and thickening. In a single-stage system, the secondary digester is replaced by some other thickening process.

The process converts about 50 percent of the organic solids to liquid and gas, greatly reducing the amount of sludge to be disposed. About two-thirds of the gas produced in the process is methane. Overall the gas has a heat value of approximately 600 BTU/standard cubic foot (scf). About 15 scf of gas is formed per pound of volatile solids destroyed. Anaerobic digester gas has been used in wastewater treatment plants for many years to heat digesters and buildings and as fuel for engines that drive pumps, air blowers and electrical generators.

Typical Design Considerations

The most important design factor is the organic loading rate, calculated as the pounds of volatile solids fed per day per cubic foot of active digester volume. Sample calculations are as follows:

1. Raw sludge feed = 8000 lb/day
   Volatile solids content = 70 percent
   Original digesters volume = 50,000 cu ft
   Diameter = 50 feet
2. Amount of volatile solids = 8000 x .7
   = 5600 lb/day
3. Original organic loading = $\frac{5600}{50{,}000}$ = 0.11 lb VS/cu ft/day
4. Assume the digester has a scum blanket of 5 feet and a grit layer of 3 feet. This reduces the volume of the digester:
   Volume reduction = $\frac{\text{Depth} \times (\text{Diameter})^2 \times 3.14}{4}$
   = $\frac{8 \times 2500 \times 3.14}{4}$
   = 15,700 cu ft

5. Usable volume = Original volume - volume reduction
= 50,000 - 15,700
= 34,300 cu ft

6. Actual organic loading = $\frac{\text{Amount of volatile solids}}{\text{Usable volume}}$
= $\frac{5600}{34,300}$
= 0.16 lb VS/cu ft/day

The increase in the original organic loading of 0.11 lb VS/cu ft/day to 0.16 lb VS/cu ft/day due to a heavy scum layer and grit buildup may cause more frequent upsets and make the digester harder to operate.

Another important factor is the hydraulic loading rate. This is the average time in days that the liquid stays in the digester and is related to digester capacity. This is calculated as follows:

1. Determine digester volume and feed volume
Digester volume = 50,000 cu ft x $\frac{7.48 \text{ gal}}{\text{cu ft}}$
= 374,000 gal
Feed volume = 19,100 gal/day

2. Calculate hydraulic loading
Hydraulic loading = $\frac{\text{Digester volume}}{\text{Feed volume}}$
= $\frac{374,000}{19,100}$
= 19.6 days

Typical design criteria for loading rates are as follows:

Parameter	Low rate digester	High rate
Solids loading, lb VS/cu ft/day	0.04-0.1	0.15-0.40
Hydraulic loading, days	30-60	10-20

Typical Performance Evaluation

Digester performance is usually expressed as percent reduction in volatile solids or as volume of digester gas produced per pound of volatile solids destroyed. Typical values are shown below:

Parameter	Performance Range
Volatile solids, reduction %	40-60%
Digester gas production, cu ft/lb VS destroyed	13-18

Process Control

Proper control of anaerobic sludge digestion is based on:

- Food supply
- Time and temperature
- Mixing
- pH and alkalinity
- Gas production

These factors are discussed in Reference 1.

Maintenance Considerations

The features of a good maintenance program are:

1. Daily check of the sludge pumping system including motors, pumps, packing, suction, meters and clocks.
2. Daily check of boiler and heat exchanger operation, temperature and pressures.
3. Daily check of digesters including mixing devices, covers, and gas collection devices.
4. Regular inspections of:
    - (a) gas safety devices
    - (b) gas piping system, compressors and scrubbers
    - (c) water seals
    - (d) manometers
    - (e) digester structure and heat transfer system
    - (f) scum blanket build-up
    - (g) equipment lubrication
5. Digester soundings performed semi-annually to determine volume reduction from accumulation of solids and to determined temperature profile.
6. Safety equipment such as flame traps, vacuum breakers, waste gas burners, condensate traps, pressure relief valves, and combustible gas detection alarms properly maintained.
7. Instrumentation regularly inspected and calibrated.

Records

Recommended sampling and laboratory tests are shown on Figures 30-1 and 30-2.

Other operating records should include

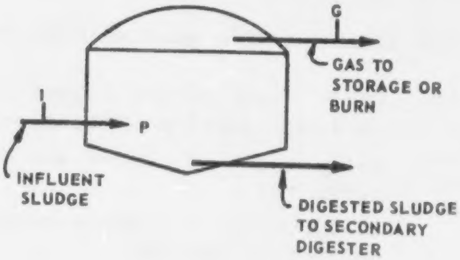
1. Production rates of CH_4 and CO_2 gases
2. Influent sludge flow
3. Grit depth
4. Depth of scum layer

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TEMPERATURE	ALL	Mn	P	Mn	P
	pH	ALL	1/D	P	G	P
	ALKALINITY	ALL	1/D	P	G	P
	VOLATILE ACIDS	ALL	3/W	P	G	P
	TOTAL SOLIDS	ALL	1/W	P	G	P
	TOTAL VOLATILE SOLIDS	ALL	1/W	P	G	P
	TOTAL VOLATILE SOLIDS	ALL	2/W	I	G	P
OPTIONAL	GAS	>5	1/W	G	G	P
	GREASE	ALL	1/M	I P	G	P

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SOLIDS REDUCTION

ANAEROBIC DIGESTION – PRIMARY



A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
P = PROCESS
G = GAS (INCLUDE WITH PROCESS TESTING)

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

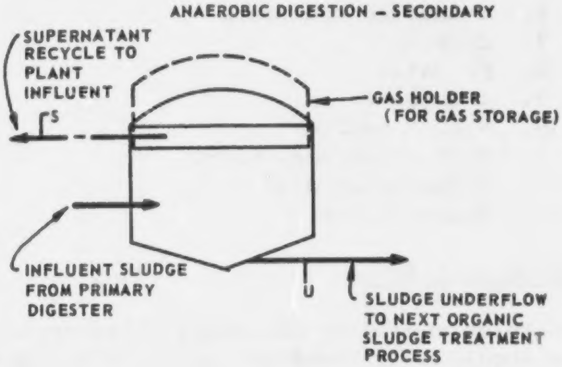
E. FOOTNOTES:

Figure 30-1

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SOLIDS REDUCTION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	pH	ALL	Mn	S[1]	Mn	P
	TOTAL SOLIDS	ALL	[2]	U	G	H
	TOTAL VOLATILE SOLIDS	ALL	[2]	U	G	H
	BOD	ALL	1/W	S	G	P[3]
	SUSPENDED SOLIDS	ALL	1/W	S	G	H
	FLOW	ALL	R	S	R	P[3]
OPTIONAL						


ANAEROBIC DIGESTION – SECONDARY
SUPERNATANT RECYCLE TO PLANT INFLUENT
S
GAS HOLDER (FOR GAS STORAGE)
INFLUENT SLUDGE FROM PRIMARY DIGESTER
U
SLUDGE UNDERFLOW TO NEXT ORGANIC SLUDGE TREATMENT PROCESS

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

U = UNDERFLOW
S = SUPERNATANT

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. IN DIGESTER (INCLUDE WITH PROCESS TESTING)
2. WHEN SLUDGE IS DRAWN OFF
3. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 30-2

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor anaerobic digestion:

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Imhoff cones
6. Graduated cylinders
7. Burettes
8. pH meter
9. Crucibles
10. Vacuum source
11. Muffle furnace, 550°C
12. Evaporating dish
13. Bunsen burner

Sampling Procedures

Samples should be collected at points where good mixing occurs. Sample ports should be allowed to run for a few moments to purge the line before sampling. Always run pH and temperature tests within 10 minutes to avoid deterioration. The remainder of the sample should be refrigerated if the other tests are not run immediately. When storing a sludge sample in a refrigerator, it is a good idea to use a plastic wrap over the jar with a rubber band to hold it in place. This will allow any gases that might collect in the sample to expand without bursting the jar. The sample container should be cleaned thoroughly before and after each use.

Sidestreams

Supernatant is returned to the head of the plant; however, this recycle stream may greatly increase the BOD, SS, and ammonia nitrogen loading on the plant. Table 30-1 presents typical digester supernatant quality data.

TABLE 30-1. DIGESTER SUPERNATANT QUALITY

	Primary plants (mg/l)	Trickling filters* (mg/l)	Activated sludge plants* (mg/l)
Suspended solids	200-1,000	500- 5,000	5,0000-15,000
BOD_5	500-3,000	500- 5,000	1,000-10,000
COD	1,000-5,000	2,000-10,000	3,000-30,000
Ammonia as NH_3	300- 400	400- 600	500- 1,000
Total phosphorus as P	50- 200	100- 300	300- 1,000

* Includes primary sludge.

Process Checklist - Anaerobic Digesters

1. What is the type of digester? ____________ High rate ______ Low rate ________ primary tank ________ primary and secondary tanks ____________
2. What type of sludge is digested? ____________
3. What type of covers are used? ( ) fixed ( ) floating ( ) none
4. What is the digester volume ________ cu ft?
5. What is the volume of the influent sludge ________ gal/day?
6. What is the design influent flow ________ gal/day?
7. What is the influent solids concentration ______%?
8. What is the volatile solids content of the influent sludge ______ %?
9. What is the design volatile solids loading ________lb/cu ft/day?
10. What is the frequency and duration of the sludge feed pumping? ______
11. What is the depth of the scum blanket ______ft?
12. What is the depth of the grit layer ______ft?
13. What is the active capacity of the digester ______ cu ft?
14. What is the actual volatile solids loading ________ lb/cu ft/day?
15. What is the hydraulic loading ______days?
16. What is the gas production rate ______ cu ft/lb VS destroyed?
17. What is the average CO_2 content of the gas ______%
18. What is the average CH_4 (methane) content of the gas______%?
19. What is the average reduction in volatile solids ______%?
20. What type of mixing is used in the primary tank? ____________
21. What are the heating provisions? ____________
22. What is the solids concentration of the sludge withdrawn from the digester ______%?
23. What is the average pH of the digester ______?
24. What is the average temperature ______°F?
25. What is the average alkalinity ______mg/l?
26. What is the average volatile acids content ______ mg/l?
27. At what point in the plant flow is the supernatant returned? ______
28. Is treatment of the supernatant provided before return to the plant? ( ) Yes ( ) No
29. Are there metering provisions for return of supernatant? ( ) Yes ( ) No
30. What is the average return flow of the supernatant ______gal/day?
31. What is the average BOD of the supernatant ______mg/l?
32. What is the average suspended solids content in the supernatant ____mg/l
33. Frequency of maintenance inspection by plant personnel for: sludge pumping ____/year; digesters and mixing equipment ____/year; gas collection/storage equipment ____/year; safety devices ____/year
34. Is maintenance program adequate? ( ) Yes ( ) No
35. Does the unit show signs of overload?
36. Is there an alarm system for hazardous equipment failures?
37. Frequency of tank cleaning ______?
38. Does the sampling program meet the recommendations?
39. Are operating records adequate?
40. Is the laboratory equipped for the necessary analyses?

41. What spare parts are stocked? ________________________________

____

____

42. What are the most common problems the operator has had with the process?

____

____

____

____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. Operations Manual - Anaerobic Sludge Digestion, EPA 430/9-75-001

31. AEROBIC DIGESTION

Process Digestion

Aerobic digestion is the separate aeration of waste sludge in open or closed tanks. The purpose is to further treat the sludge so it will not cause odors or other nuisances in final disposal. Aerobic digestion also reduces the volume of sludge solids. Aerobic digestion is used commonly for package plants. It is equally useful for larger plants especially for waste biological sludges.

Aerobic digestion is a completely mixed activated sludge system with either batch or continuous flow input. The contents of the digestor are aerated for a period of 12 to 22 days depending on the type of sludge. The solids resulting from digestion are separated from the liquid. They dewater easily and do not cause odor problems.

Typical Design Considerations

Typical design criteria for aerobic digestion are shown in Table 31-1, which was adapted from "Process Design Manual for Sludge Treatment and Disposal", EPA 625/1-74-016.

Solids Retention Time (SRT) is the average time that the solids remain in the process. For continuous feed systems:

$$SRT = \frac{\text{total mass of solids in digester}}{\text{mass of solids wasted/day}}$$

For batch feed systems:

$$SRT = \frac{\text{average mass of the solids in digester during batch}}{\text{(mass of solids wasted from batch) (number of days in batch}}$$

As an example assume the following data:

Continuous feed:

Tank volume = 65,000 gal Solids = 2.5%
Wasting rate = 2000 gal/day Solids = 5.0%

$$SRT = \frac{65{,}000 \times 0.025}{2{,}000 \times 0.05} = 16.3 \text{ days}$$

TABLE 31-1. AEROBIC DIGESTION DESIGN PARAMETERS

Parameter	Value	Remarks
Solids retention time, days	10-15[a]	Depending on temperature, type of sludge, etc.
Solids retention time, days	15-20[b]	
Volume allowance, cu ft/capital	3-4	
VSS loading, pcf/day	0.024-0.14	Depending on temperature, type of sludge, etc.
Air requirements Diffuser system cfm/1,000 cu ft	20-35[a]	Enough to keep the solids in suspension and maintain a DO between 1-2 mg/l.
Diffuser system, cfm/1,000 cu ft	>60[b]	
Mechanical system, hp/1,000 cu ft	1.0-1.25	This level is governed by mixing requirements. Most mechanical aerators in aerobic digesters require bottom mixers for solids concentration greater than 8,000 mg/l, especially if deep tanks (>12 feet) are used.
Minimum DO, mg/l	1.0-2.0	
Temperature, °C	>15	If sludge temperatures are lower than 15°C, additional detention time should be provided so that digestion will occur at the lower biological reaction rates.
VSS reduction, percent	35-50	
Tank design		Aerobic digestion tanks are open and generally require no special heat transfer equipment or insulation. For small treatment systems (0.1 mgd), the tank design should be flexible enough so that the digester tank can also act as a sludge thickening unit. If thickening is to be utilized in the aeration tank, sock type diffusers should be used to minimize clogging.
Power requirement, BHP/10,000 Population Equivalent	8-10	

---

[a] Excess activated sludge alone.

[b] Primary and excess activated sludge, or primary sludge alone.

Batch feed with sludge settling and drawoff once per week:

Sludge volume in digester at beginning of week: 40,000 gal
Sludge volume in digester at end of week: 65,000 gal
Solids = 2.5%
Total of supernatant and settled sludge drawoff: 25,000 gal
Number of days in batch = 7

$$\text{Average volume of sludge in digester} = \frac{40{,}000 + 65{,}000}{2} = 52{,}500$$

$$\text{SRT} = \frac{52{,}500 \times 0.025}{25{,}000 \times 0.025} \times 7 = 15 \text{ days}$$

The volatile suspended solids (VSS) loading, expressed as pounds of VSS per cubic foot of basin volume per day, is calculated as shown in the following example for a continuous feed digester.

Tank volume = 65,000 gal
Wasting rate = 2,000 gal/day @ solids = 5.0%
Waste activated sludge, volatile solids = 80% of TSS

$$\text{Total VSS wasting rate} = 2{,}000 \ \frac{\text{gal}}{\text{day}} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.05 \times 0.80 = 667 \ \frac{\text{lb VSS}}{\text{day}}$$

$$\text{VSS loading rate} = \frac{667}{65{,}000 \text{ gal}} \times \frac{7.48 \text{ gal}}{\text{cu ft}} = 0.077 \text{ lb VSS/cu ft/day}$$

Typical Performance Evaluation

With aerobic digestion a 40 to 50 percent reduction in volatile suspended solids content is normally obtained. The supernatant may contain as little as 10 to 30 mg/l BOD, 10 mg/l ammonia nitrogen, and from 50 to 100 mg/l nitrate nitrogen. When nitrification occurs, both pH and alkalinity are reduced.

Process Control

In most plants the aerobic digester is operated as a self-regulating process with very little process control needed. That which is needed is discussed in Reference 6.

Maintenance Considerations

The maintenance program for the aerobic digester is very similar to the program for the activated sludge process. The features of a good maintenance program that the inspector should look for are:

1. Air diffusers and tanks inspected at least once per year.
2. Mixing, pumping, and blower equipment inspected annually for worn blades and impellers.
3. Air filters serviced at regular intervals.

4. Digester inspected once per shift for proper operation of aeration equipment and pumps.

Records

Recommended sampling and laboratory tests are shown in Figure 31-1.

Other operating records should include:

1. Volume of sludge recycled to aerobic digester.
2. Frequency and duration of operation of sludge pumps.
3. Periods when a digester is not operated because of inspection and service.
4. Days when there are problems with mixing and/or odors.

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor aerobic digestion:

1. Thermometer
2. pH meter
3. Analytical balance
4. Clinical centrifuge with graduated tubes
5. BOD incubator
6. Drying oven
7. Muffler furnace
8. Oxygen gas analyzer (optional)

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

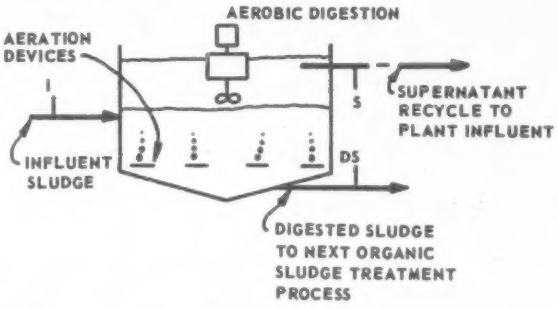
Sampling should be performed as outlined under Records. These samples may be obtained through valves provided in the digester piping. If sampling points are not provided, it may be necessary to obtain samples directly from the digester contents.

The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Samples collected in the effluent channel should be collected near the discharge point so that any isolated areas of short circuiting do not influence the results. Where automatic samplers are used, it is important to keep the sampler tubes clean.

Samples should be analyzed according to procedures specified in Standard Methods.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SOLIDS REDUCTION


AEROBIC DIGESTION
AERATION DEVICES
I
INFLUENT SLUDGE
S
SUPERNATANT RECYCLE TO PLANT INFLUENT
DS
DIGESTED SLUDGE TO NEXT ORGANIC SLUDGE TREATMENT PROCESS

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TEMPERATURE	ALL	1/D	P	G	H
	pH	ALL	1/D	P	G	H
	TOTAL SOLIDS	ALL	2/W	I DS	G	H
	TOTAL VOLATILE SOLIDS	1	2/W	I DS	G	H
	DO	ALL	3/W	P	G	P
	AIR INPUT[1]	ALL	R	B	R	P C
	SETTLEABLE SOLIDS	ALL	3/W	P	G	H
	FLOW	ALL	R	DS	R	P
	pH	ALL	[2]	S	G	H
	SUSPENDED SOLIDS	ALL	[2]	S	G	H
	BOD	ALL	[2]	S	G	P[3]
	FLOW	ALL	R	S	R	P[3]
OPTIONAL						
	ALKALINITY	ALL	2/W	P	G	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
DS = DIGESTED SLUDGE
S = SUPERNATANT
P = PROCESS
B = BLOWER (INCLUDE WITH PROCESS TESTING)

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. DIFFUSED AIR ONLY
2. WHEN DRAW OFF SUPERNATANT
3. FOR CONTROL OF PROCESS RECEIVING THIS FLOW

Figure 31-1

Sidestreams

The only sidestream from the aerobic digestion process is the supernatant. It is returned to either the primary or the secondary treatment process and normally causes no problem to process operation.

Process Checklist - Aerobic Digestion

1. How many aerobic digestion units are there ____________?
2. What are the dimensions of each unit ____________________________________?
3. How many units are presently operating ________________?
4. What type of sludge is treated in the aerobic digesters (waste activated, primary, primary + waste activated, etc.) ______________________?
5. What is the volume of influent sludge flow _______________gal/day average?
6. What is the design sludge flow __________________________ gal/day average?
7. How often is sludge applied to the digester _______________times per day?
8. What is the total duration of influent pumping _____________hours/day?
9. Is influent sludge pumping ( ) manual ( ) automatic?
10. What is the solids concentration in the influent sludge flow ___________%?
11. What is the solids concentration in the aerobic digesters ______________%?
12. What type of aeration equipment is used (diffused, mechanical, combination, etc.) ______________________?
13. If diffused aeration is used, do air diffusers require frequent cleaning? ( ) Yes ( ) No
14. Are the aerobic digesters ( ) open ( ) closed?
15. Is the aeration ( ) conventional ( ) pure oxygen?
16. What is the sludge retention time (SRT) _____________days?
17. What is the volatile suspended solids (VSS) loading _____________ lb VSS/cu ft/day?
18. Is a separate sedimentation tank used or is it a batch-type system? __________________________________
19. See Primary Clarification or Secondary Sedimentation for a checklist for sedimentation tanks.
20. What is the solids concentration of the sludge following settling ________?
21. How much waste sludge is pumped __________________ gallons/day?
22. How often do waste sludge pumps run ________________ minutes/hour?
23. Is waste sludge pumping ( ) manual ( ) automatic?
24. How much sludge is recycled back to the aerobic digester ______________ gallons/day average?
25. What percentage of the influent sludge flow is the recycle sludge flow ___________%?
26. Are the contents of the tanks well mixed and relatively free of odors? ( ) Yes ( ) No
27. Is there a foaming problem? ( ) Yes ( ) No
28. What is the dissolved oxygen (DO) concentration in the aerobic digestion units _____________mg/l?
29. Are there provisions for pH adjustment by the addition of lime, sodium hydroxide, or sodium bicarbonate? ( ) Yes ( ) No
30. What is the volume of supernatant flow ___________gal/day average?
31. What is the BOD of the supernatant flow ___________ mg/l?
32. What is the suspended solids concentration of the supernatant _________ mg/l?
33. What is the nitrate nitrogen concentration of the supernatant _________ mg/l?
34. What is the ammonia nitrogen concentration of the supernatant _________ mg/l?
35. Frequency of maintenance inspections by plant personnel __________/year.

36. Is maintenance program adequate? ( ) Yes ( ) No
37. If multiple units are used, is the flow distributed evenly?
( ) Yes ( ) No
38. Does the unit show signs of short circuiting and/or overloads?
( ) Yes ( ) No
39. Is there an alarm system for equipment failures or overloads?
( ) Yes ( ) No
40. Does the sampling program meet the recommendations? ( ) Yes ( ) No
41. Are operating records adequate? ( ) Yes ( ) No
42. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
43. What spare parts are stocked? ______________________________

44. What are the most common problems the operator has had with the process?

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Harrison, J.R., Goodson, J.B., and Culp, G.L., Process Design Manual for Sludge Treatment and Disposal, USEPA, 625/1-74-006.

6. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

32. CENTRIFUGATION

Process Description

The centrifuge is a sedimentation device in which the solids-liquid separation is enhanced by rotating the liquid at high speeds. Centrifuges have been used for both sludge thickening and dewatering especially for waste activated sludge and digested sludges. Both the disc type and the solid bowl centrifuges are well suited to thickening operations.

The solid bowl centrifuge is the most widely used type for dewatering of sewage sludge. It consists of a rotating bowl and conveyor. Sludge enters the rotating bowl through a stationary feed pipe extending into the hallow shaft of the rotating screw conveyor and is distributed through ports into a pool within the rotating bowl. The helical rotating conveyor moves the sludge solids across the bowl, up the beaching incline to outlet ports and then to a sludge cake discharge hopper.

Water or centrate is discharged from the bowl through ports in the end which maintain the pool in the bowl at the desired depth.

The basket centrifuge is also referred to as the imperforate bowl, knife discharge type and is a batch dewatering unit that rotates around the vertical axis. The sludge is charged into the basket and forms an annular ring as the unit rotates. The liquid (centrate) is displaced over a baffle or weir at the top of the unit. When the solids concentration reaches the desired limit the centrifuge is stopped. A knife or skimmer displaces the cake from the vertical wall and out the bottom openings.

The disc centrifuge is continuous flow variation of the basket centrifuge. It is prone to plugging and in some cases the sludge may have to be screened prior to centrifugation.

Typical Design Considerations

The most commonly used loading factor for centrifuges is the sludge feed rate. Single centrifuge capacities range from 4 gpm to about 250 gpm. Feed rates may also be given in pounds of dry solids per hour. This is calculated as shown on the following page.

1. Determine wet sludge feed rate.
   Feed rate = 150 gpm

2. Determine solids concentration in the feed sludge.

$$\text{Concentration} = \frac{\text{weight of dry sludge solids}}{\text{weight of wet sludge}} \times 100\%$$

$$= \frac{0.1 \text{ lb}}{10 \text{ lb}} \times 100 = 1\%$$

3. Calculate dry feed rate.

$$\text{Dry feed rate} = \text{sludge wet feed rate} \times \text{concentration}$$

$$= 150 \times 0.01 \times 8.34 \ \frac{\text{lb}}{\text{gal}} \times 60 \ \frac{\text{min}}{\text{hr}}$$

$$= 750 \text{ lb dry solids/hr}$$

   Typical feed rates for several sizes of solid bowl centrifuges for typical municipal waste sludges are:

Machine size, in	Feed rate lb dry solids/hr
18	300 x 800
24	700 to 2000
36	1500 to 3500

4. Solids recovery is the ratio of cake solids to feed solids for equal sampling times. It can be calculated with suspended solids and flow data or with only suspended solids data. The centrate solids must be corrected if chemicals are fed to the centrifuge.

$$\text{Recovery} = \frac{\text{wet cake flow, } \frac{\text{lb}}{\text{hr}} \quad (\text{cake solids, } \%) \quad (100)}{\text{wet feed flow, } \frac{\text{lb}}{\text{hr}} \quad (\text{feed solids, } \%)}$$

$$\text{Recovery} = \frac{(\text{cake solids, } \%)\ (\text{feed solids, } \% - \text{centrate solids, } \%)\ (100)}{(\text{feed solids, } \%)\ (\text{cake solids, } \% - \text{centrate solids, } \%)}$$

5. Centrate solids must be corrected if chemicals are added to centrifuge. Because it is diluted by the extra water from the chemical and chemical dilution water feeds. The measured centrate solids, therefore, are less than the actual solids would be without the added water from the chemical feed.

$$\text{correction factor} = \frac{(\text{feed rate, gpm}) + (\text{chemical flow, gpm}) + (\text{dilution water, gpm})}{\text{feed rate, gpm}}$$

   corrected centrate solids =
   (measured centrate solids) (correction factor)

Typical Performance Evaluation

Expected centrifuge performance is shown in Table 32-1 for a number of conditions. These data were developed from "Process Design Manual for Sludge Treatment and Disposal", EPA 625/1-74-006 and actual plant data.

TABLE 32-1. EXPECTED CENTRIFUGE PERFORMANCE

	Sludge Cake Characteristics		
Wastewater sludge type	**Solids, %**	**Solids recovery, %**	**Polymer addition**
Raw or digested primary	25-35	90-95	2-4 lbs/ton
	28-35	70-90	no
Raw or digested primary, plus trickling filter humus	20-30	80-95	5-15 lbs/ton
	25-35	60-75	no
Raw or digested primary, plus activated sludge	15-30	80-95	5-20 lbs/ton
	15-25	50-65	no
Activated sludge	9-9	80-85	5-10 lbs/ton
Oxygen activated sludge	8-10	80-85	3-5 lbs/ton
High-lime sludges	50-55	90	no
Lime classification	50	75	no
Heat treated sludge	30-50	85-90	no
Heat treated sludge	30-50	92-99	2-5 lbs/ton

Typical Thickening Performance
(Based on limited plant operating experience)

Type of sludge	Centrifuge type	Underflow solids, %	Feed solids, %	Solids recovery, %	Polymer requirement, lb/ton
WAS	Disc	4-5.5	0.75-1.0	80-90	None
EAS (after roughing filter)	Disc	5-7	0.7	80-97	None
EAS	Basket	9-10	0.7	90-70	None
EAS	Solid-bowl	5-13	0.4-1.5	70-90	None
				85	5
				90	5-10
				95	10-15

WAS = waste activated sludge
EAS = extended aeration waste sludge

Process Control

There are several variables that can be controlled by the operator to affect optimum centrifuge performance. These are presented in Reference 6.

Maintenance Considerations

The features of a good maintenance program include general maintenance requirements as well as the following:

1. Conveyor belts properly checked for adjustment.
2. Spare part inventory contain the following: shear pins, main bearings, seals, conveyor bushings, thrust bearing seal, feed and discharge ports.

Records

Recommended sampling and laboratory tests are shown in Figure 32-1.

Other operating records should include:

1. Frequency and duration of centrifuge operating time.
2. Quantity of sludge cake produced.
3. Influent sludge flow.

Laboratory Equipment

The laboratory should include the following equipment in order to monitor centrifugation:

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Imhoff Cones

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples should be collected at the points shown under the section Records. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used. Where automatic samplers are used, it is important to keep the sampler tubes clean.

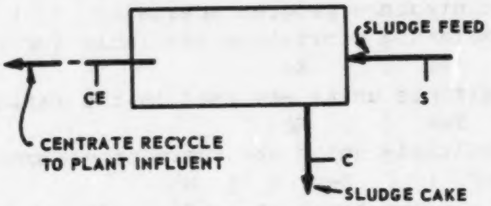
Sidestreams

The centrate is usually returned to the plant influent or some other appropriate point in the main treatment process. Return of centrate to flotation thickeners has also proven satisfactory.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SLUDGE CONCENTRATION

CENTRIFUGATION (1)



NOTE: SOLID BOWL TYPE SHOWN. FLOW PATTERN IS SIMILAR FOR OTHER MODELS.

SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	1/D	S C	G	P
BOD	ALL	1/W	CE	G	P[2]
SUSPENDED SOLIDS	ALL	1/D	CE	G	P
SETTLEABLE SOLIDS	ALL	1/H	CE	G	P
FLOW	ALL	R	CE	R	P[1]

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

S = SLUDGE FEED
C = SLUDGE CAKE
CE = CENTRATE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. DAILY OPERATION ASSUMED
2. FOR CONTROL OF PROCESS RECEIVING THIS FLOW.

Figure 32-1

Process Checklist - Centrifugation

1. What is the volume of influent sludge flow ______________ gal/min?
2. What is the design flow ______________ gal/min?
3. How much cake is produced ? ______________ lb/day?
4. What is the solids concentration in the influent sludge? ____________ %
5. What type and size of centrifuges are used? ______________________
6. What is the solids recovery ______________ %
7. What is the solids concentration in the discharge cake ______________ %
8. Is operation of centrifuge, conveyors or sludge feed pumping ( ) manual ( ) automatic.
9. How often does the centrifuge run ______________ min/hr?
10. Frequency of maintenance inspections by plant personnel ____________ /yr
11. Is maintenance program adequate? ( ) Yes ( ) No
12. Are metering provisions available for return of the centrate? ( ) Yes ( ) No
13. If multiple units are used is the influent flow distributed evenly? ( ) Yes ( ) No
14. For multiple units are there provisions for equalization of centrate flows? ( ) Yes ( ) No
15. What are the types of conditioning chemicals fed? ______________________
16. What amounts of chemicals are fed ____________ lb/day?
17. What are chemical feed cycle times ______________ minutes/hr?
18. Is the general housekeeping satisfactory? ( ) Yes ( ) No
19. Does the unit show signs of overloading? ( ) Yes ( ) No
20. Does the unit show signs of excessive wear? ( ) Yes ( ) No
21. Is there an alarm system for equipment failures or overloads? ( ) Yes ( ) No
22. Does the sampling program meet the recommendations? ( ) Yes ( ) No
23. Are operating records adequate? ( ) Yes ( ) No
24. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
25. What spare parts are stocked? ____

27. What are the most common problems the operator has had with the process? ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).
3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).
4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).
5. State of Virginia O&M inspection form.
6. Harrison, J.R., Goodson, J.B., and Culp, G.L., Process Design Manual for Sludge Treatment and Disposal, USEPA, 625/1-74-006.
7. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

33. VACUUM FILTRATION

Process Description

A vacuum filter consists of a cylindrical drum which rotates partially submerged in a vat of sludge. The filter drum is divided into compartments by partitions or seal strips. A vacuum is applied between the drum deck and filter medium causing filtrate to be removed and filter cake to be retained on the medium during the pickup and cake drying cycle. The filter medium may be a cloth made of natural or synthetic fibers, stainless steel wire mesh or coil springs. Dewatered sludge is ordinarily removed by a fixed scraper blade.

Typical Design Considerations

The most important loading factor is the amount of solids, on a dry basis, applied to the filter per hour. This is called the "solids loading rate" and is expressed in pounds of solids per square foot of vacuum filter area per hour. This factor is calculated as shown in the following example. Typical values are shown in Table 33-1.

1. Determine effective surface area of vacuum filter. The plant construction drawings or the vacuum filter O&M manual should contain the necessary information.
   Area = 75 sq ft
2. Determine sludge flow to vacuum filter from plant records (must include chemicals).
   Sludge flow = 100,000 gal/hr
3. Determine the influent sludge concentration.

$$\text{Concentration} = \frac{\text{weight of dry sludge solids}}{\text{wet of wet sludge}} \times 100\%$$

$$= \frac{1\ \text{lb}}{10\ \text{lb}} \times 100 = 10\%$$

4. Determine the total dry weight of sludge to the vacuum filter per hour.

$$\text{Dry weight} = \text{sludge flow} \times \text{concentration} - 8.34$$

$$= \frac{100{,}000 \times 0.1}{8.34} = 1200\ \text{lb/hr}$$

5. Determine loading rate.

$$\text{Loading rate} = \frac{\text{Dry weight}}{\text{Area}}$$

$$= \frac{1200}{150} = 8\ \text{lb/sq ft/hr}$$

Typical Performance Evaluation

The most common measure of performance for vacuum filters is the yield. This is expressed in terms of pounds of dry total solids in the cake discharged from the filter per square foot of effective filter area per hour.

Performance of the vacuum filtration process can vary widely depending on the sludge type, sludge characteristics, conditioning, type of vacuum filter, and loading rates. Typical applications are shown in Table 33-1.

TABLE 33-1. VACUUM FILTRATION TYPICAL LOADINGS AND PERFORMANCE

Sludge type	Design assumptions	Feed solids, %	Typical loading rates, psf/hr	Performance cake solids, %
Primary	Thickened to 10% solids polymer conditioned	10	8-10	25-38
Primary + $FeCl_3$	85 mg/l $FeCl_3$ dose Lime conditioning Thickening to 2.5% solids	2.5	1.0-2.0	15-20
Primary + Low Lime	300 mg/l lime dose Polymer conditioned Thickened to 15% solids	15	6	32-35
Primary + High Lime	600 mg/l lime dose Polymer conditioned Thickened to 15% solids	15	10	28-32
Primary + WAS	Thickened to 8% solids Polymer conditioned	8	4-5	16-25
Primary + (WAS + $FeCl_3$)	Thickened to 8% solids $FeCl_3$ & lime conditioned	8	3	20
(Primary + $FeCl_3$) + WAS	Thickened primary sludge to 2.5% Flotation thickened WAS to 5% Dewater blended sludges	3.5	1.5	15-20
Waste Activated Sludge (WAS)	Thickened to 5% solids Polymer conditioned	5	2.5-3.5	15
WAS + $FeCl_3$	Thickened to 5% solids Lime + $FeCl_3$ conditioned	5	1.5-2.0	15
Digested primary	Thickened to 8-10% solids Polymer conditioned	8-10	7-8	25-38
Digested primary + WAS	Thickened to 6-8% solids Polymer conditioned	6-8	3.5-6	14-22
Digested primary + (WAS + $FeCl_3$)	Thickened to 6-8% solids $FeCl_3$ + lime conditioned	6-8	2.5-3	16-18
Tertiary alum	Diatomaceous earth precoat	0.6-0.8	0.4	15-20

Process Control

Control of the vacuum filter systems should be based on performance. The performance of vacuum filters may be measured by various criteria such as the yield, the efficiency of solids removal, and the cake characteristics. Each of these criteria is of importance, but one or the other may be particularly significant in a given plant. Control based on these criteria is discussed in Reference 7.

Maintenance Considerations

The maintenance program vacuum filters includes sludge pumping, chemical feed systems and the filter unit itself. Maintenance items specific to the filter unit are:

1. Daily inspection of filter media for excessive or unusual wear.

2. Daily checks and lubrication of drive units.

3. Periodic cleaning of sludge lines and conveyor belts.

4. Spare parts inventory include the following: drive mechanism parts such as sprockets, chains, gears, motors, bearings, etc. and vacuum mechanism parts such as hoses, fittings, pumps, gauges, etc.

Records

Recommended sampling and laboratory tests are shown in Figure 33-1.

Other records should include:

1. Influent sludge flow
2. Concentration of influent sludge and sludge cake
3. Frequency and duration of operation

Laboratory Equipment

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

SUGGESTED MINIMUM

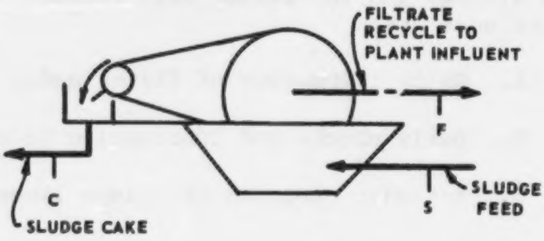
OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	1/D	S C	G	P
BOD	ALL	2/W	F	G	P^1
SUSPENDED SOLIDS	ALL	1/D	F	G	P
FLOW	ALL	R	F	R	P^1

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SLUDGE CONCENTRATION

VACUUM FILTRATION



A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

S = SLUDGE FEED
C = SLUDGE CAKE
F = FILTRATE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. FOR CONTROL OF PROCESS RECEIVING THIS FLOW.

Figure 33-1

Sampling Procedures

Sampling should be performed as outlined under Records. These samples may be obtained through valves provided in the respective thickener piping. If sampling points are not provided, they should be installed to facilitate operation and control of the process. Samples of the supernatant can be obtained at the overflow weir.

Samples should be analyzed according to procedures specified in Standard Methods.

Sidestreams

The only sidestream is the filtrate which is the liquid removed from the sludge during dewatering. Filtrate is returned to a main plant treatment process. When filtrate quality is poor, it is possible to build up a large proportion of fine solids in the plant and reduce plant treatment efficiency. In an activated sludge process, the filtrate may be returned to a flotation or thickening process.

Process Checklist-Vacuum Filtration

1. What is the volume of the influent sludge flow ________gal/day avg?
2. What is the percent solids of the influent sludge ____________%
3. What is the effective area of the vacuum filter __________sq ft?
4. What is the design loading rate _________________ lb/sq ft/hr?
5. What is the percent solids in the discharge cake ____________%
6. Are there settleable solids in the filtrate ____________mg/liter?
7. How often does vacuum filter run ___________ minutes/hour?
8. Frequency of maintenance inspections by plant personnel ______/year
9. Is maintenance program adequate? ( ) Yes ( ) No
10. Is the vacuum system inspected regularly _________/year?
11. Frequency of maintenance inspections for chemical feed system
    ________/year
12. What type of conditioning chemicals are used________________?
13. What amount of conditioning chemicals are pumped _________lb/day?
14. Are proper safety precautions used in handling these chemicals?
    ( ) Yes ( ) No.
15. Is sludge pumping ( ) manual ( ) automatic?
16. Is chemical feed ( ) manual ( ) automatic?
17. How often do sludge pumps run _____________minutes/hour?
18. How often does conditioning equipment run __________minutes/hour?
19. If multiple units are used, is the flow distributed evenly?
    ( ) Yes ( ) No
20. Does the unit show signs of short circuiting and/or overloads?
    ( ) Yes ( ) No
21. Is there an alarm system for equipment failures or overloads?
    ( ) Yes ( ) No
22. Does the sampling program meet the recommendations? ( ) Yes ( ) No
23. Are operating records adequate? ( ) Yes ( ) No
24. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
25. What spare parts are stocked? ______________________________
    ____
    ____
26. What are the most common problems the operator has had with the process?
    ____
    ____
    ____
    ____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. Harrison, J.R., Goodson, J.B., and Culp, G.L., Process Design Manual for Sludge Treatment and Disposal, USEPA, 625/1-74-006.

7. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

34. PRESSURE FILTRATION

Process Description

The filter press is a batch device used to dewater sludges. There are several types of presses available but the most common consists of vertical plates which are held in a frame and which are pressed together between a fixed and moving end. A cloth is mounted on the face of each individual plate. Despite its name, the filter press does not close to squeeze or press sludge. Instead, the press is closed and then sludge is pumped into the press at pressures up to 225 psi and passes through feed holes in the trays along the length of the press. Filter presses usually require a precoat material (incinerator ash or diatomaceous earth are typically used) to aid in solids retention on the cloth and release of the cake.

The water passes through the cloth, while the solids are retained and form a cake on the surface of the cloth. Sludge feeding is stopped when the cavities or chambers between the trays are filled. Drainage ports are provided at the bottom of each press chamber. The filtrate is collected in these, taken to the end of the press, and discharged to a common drain.

The pressures which may be applied to a sludge for removal of water by filter presses now available range from 5,000 to 20,000 times the force by gravity. In comparison, a solid bowl centrifuge provides forces of 700 to 3,500 times the force of gravity and a vacuum filter, 1,000 times the force of gravity. As a result of these greater pressures, filter presses may provide higher cake solids concentrations (30 to 50 percent solids) at reduced chemical dosage. In some cases, ash from a downstream incinerator is recycled as a sludge conditioner.

Typical Design Considerations

Typical loading rates for pressure filtration of various sludges are shown in Table 34-1. This data was developed from "Process Design Manual for Sludge Treatment and Disposal," (EPA 625/1-74-006). Loading rates depend on the length of the dewatering cycle described above.

Typical Performance Evaluation

Typical performance criteria for pressure filters are the pressing cycle length, the solids content of the cake, and the quality of the filtrate. Performance of filter press on various sludges will vary widely, but the data in Table 34-1 are typical.

Process Control

Instrumentation is usually minimal, however, it is possible to completely automate the operation of the filter press if desired. Pressure gauges should be provided to monitor the feed pressures and the filtrate flow must be monitored either visually or with a flow indicator. Details of process control are given in Reference 7.

TABLE 34-1. TYPICAL RESULTS PRESSURE FILTRATION

Sludge type	Conditioning	Feed solids, %	Typical cycle length, hr	% solids filter cake solids, %
Primary	5% $FeCl_3$, 10% Lime 100% Ash	5	2 1.5	45 50
Primary + $FeCl_3$	10% Lime	4*	4	40
Primary + 2 stage high lime	None	7.5	1.5	50
Primary + WAS	5% $FeCl_3$, 10% lime 150% Ash	8*	2.5 2.0	45 50
Primary + (WAS $FeCl_3$)	5% $FeCl_3$, 10% Lime	8*	3	45
(Primary + $FeCl_3$) + WAS	10% Lime	3.5*	4	40
WAS	7.5% $FeCl_3$, 15% Lime 250% Ash	5*	2.5 2.0	45 50
WAS + $FeCl_3$	5% $FeCl_3$, 10% Lime	5*	3.5	45
Digested Primary	6% $FeCl_3$, 30% Lime	8	2	40
Digested Primary + WAS	5% $FeCl_3$, 10% Lime 100% Ash	6-8*	2 1.5	45 50
Digested Primay + (WAS + $FeCl_3$)	5% $FeCl_3$, 10% Lime	6-8*	3	40
Tertiary Alum	10% Lime	4*	6	35
Tertiary Low Lime	None	8*	1.5	55

* Thickening used to achieve this solids concentration

Maintenance Considerations

The features of a good maintenance program are:

1. A thorough semi-annual inspection of all equipment including the following.
    - a) Drive and gear reducers
    - b) Drive chains and sprockets
    - c) Closing mechanism
    - d) Bearing brackets
    - e) Electrical contacts in starters and relays
2. Filter cloths or media washed in place.
3. Rubber surfaces of the plates scraped only with soft plastic or wood to avoid damage.
4. Spare part inventory should contain the following: drives and gear reducers, drive chains, sprockets, closing mechanism, bearing brackets, and electrical contacts.

Records

Recommended sampling and laboratory tests are shown in Figure 34-1.

Other operating records should include:

1. Influent sludge flow
2. Volume of sludge cake produced
3. Frequency and duration of operation

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor vacuum filtration:

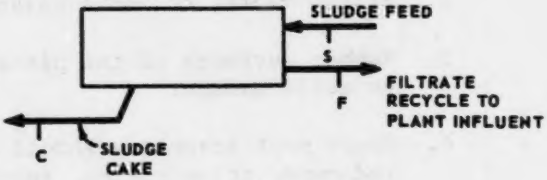
1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SLUDGE CONCENTRATION

PRESSURE FILTRATION



SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	1/D	S C	G	P
BOD	ALL	2/W	F	G	P^1
SUSPENDED SOLIDS	ALL	1/D	F	G	P
FLOW	ALL	R	F	R	P^1

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

S = SLUDGE FEED
C = SLUDGE CAKE
F = FILTRATE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. FOR CONTROL OF PROCESS RECEIVING THIS FLOW.

Figure 34-1

Sampling Procedures

Sampling should be performed as outlined under Records. These samples may be obtained through valves provided in the respective piping or directly from the process. If sampling points are not provided, they should be installed to facilitate operation and control of the process.

The sample collector and container should be clean. Samples should be analyzed according to procedures specified in Standard Methods.

Sidestreams

The only sidestream is the filtrate, which is the liquid removed from the sludge during dewatering. Filtrate quality should be very good (less than 100 mg/l suspended solids) if the system is properly operated. During the early part of the cycle, the drainage from a large press can be in the order of 2,000 to 3,000 gallons per hour. This rate falls rapidly to about 500 gallons per hour as the cake forms and at the end of the cycle the rate is virtually zero. Filtrate is normally returned to the plant treatment process.

Process Checklist - Pressure Filtration

1. What is the volume of the influent sludge flow ____________gal/day avg.
2. What is the percent solids of the influent sludge ______________%?
3. What is the filter press volume ________________ cu ft?
4. What is the percent solids in the discharge cake ___________%?
5. Are there settleable solids in the filtrate ____________mg/l?
6. How often does pressure filter run ____________________min/hr?
7. Frequency of maintenance inspections by plant personnel ___________/yr?
8. Is maintenance program adequate? ( ) Yes ( ) No
9. Frequency of maintenance inspections for chemical feed system _______/yr?
10. If acid washing is provided, is a recirculating system included?
( ) Yes ( ) No
11. What type of conditioning chemicals are used ____________?
12. What amount of conditioning chemicals are pumped ___________lb/day?
13. Are proper safety precautions used in handling these chemicals?
( ) Yes ( ) No
14. Is sludge pumping ( ) manual ( ) automatic?
15. Is chemical feed ( ) manual ( ) automatic?
16. How often do sludge pumps run ________________minutes/hr?
17. How often does conditioning equipment run _________minutes/hr?
18. If multiple units are used, is the flow distributed evenly?
( ) Yes ( ) No
19. Does the unit show signs of short circuiting and/or overloads?
( ) Yes ( ) No
20. Is there an alarm system for equipment failures or overloads?
( ) Yes ( ) No
21. Does the sampling program meet the recommendations? ( ) Yes ( ) No
22. Are operating records adequate? ( ) Yes ( ) No
23. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
24. What spare parts are stocked? ______________________________
____
____
____
25. What are the most common problems the operator has had with the process?
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. State of Virginia O&M inspection form.

6. Harrison, J.R., Goodson, J.B., and Culp, G.L., Process Design Manual for Sludge Treatment and Disposal, USEPA, 625/1-74-006.

7. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

35. DRYING BEDS

Process Description

Drying beds are generally used for dewatering of well digested sludges. Attempts to air dry raw sludge usually results in odor problems.

Sludge drying beds consist of perforated or open joint drainage pipe laid within a gravel base. The gravel is covered with a layer of sand. Partitions around and between the drying beds may be of concrete, wood or earthen embankment. Drying beds are generally open to the weather but may be covered with ventilated green-house type enclosures in wet climates.

Sand beds allow water to drain from the sludge mass through the supporting sand to the drainage piping. As the sludge dries, cracks develop in the surface allowing natural exaporation to occur from the lower layers. This speeds the drying process.

Typical Design Considerations

The most important loading factor is the solids loading rate to the drying bed. Solids loading rate is the weight of solids on a dry weight basis applied yearly per square foot of drying bed area. As an example, assume that 10 inches of 5 percent solids anaerobically digested sludge is applied to a drying bed five times per year. The weight of solids will be calculated for one square foot of bed.

Solids Loading Rate =

$$\frac{\text{dry weight of solids}}{\text{year}} \quad - \quad \frac{\text{square feet of}}{\text{drying bed}}$$

$$\frac{\text{cubic feed of sludge}}{\text{square feet of bed}} \quad \frac{\text{lbs}}{\text{ft}^3} \quad \frac{\text{\% solids}}{100} \quad \frac{\text{Number of}}{\text{applications}}$$

$$\frac{1 \times 1 \times \frac{10}{12}}{\text{sq ft of bed}} \quad \frac{62.4\ \text{lbs}}{\text{ft}^3} \quad \frac{5}{100} \quad (5)$$

$$13\ \frac{\text{lbs}}{\text{year-sq ft}}$$

Drying beds are usually sized based upon required square feet of bed area per capita (or per person) served by the treatment plant. The area required for drying beds depends on climate but typical criteria are given below for several types of digested sludge and for whether the drying beds are open or covered.

	Open beds	Covered beds
Bed sizing, sq ft/capita from WPCF, 1959:		
Primary digested sludge	1.0 - 1.5	0.75 - 1.0
Primary and humus digested sludge	1.25 - 1.75	1.0 - 1.25
Primary and activated digested sludge	1.75 - 2.5	1.25 - 1.5
Primary and chemically precipitated digested sludge	2.0 - 2.5	1.25 - 1.5

The population which can be adequately served by a set of existing drying beds can be calculated, as shown in the following example.

1. Determine drying bed shape and dimensions. The plant construction drawings and specifications include this information.

   Shape = 8 rectangular beds
   Dimensions, each bed = 20 ft x 40 ft
   Single bed area = 20 x 40 = 800 sq ft
   Total Area = 8 x 800 = 6,400 sq ft

2. Determine area required per capita.

   Sludge type = Digested primary and waste activated
   Bed type = Open beds
   Area per capita (from above summary) = 1.75 - 2.5 sq ft/capita
   Use 2.0 sq ft/capita

3. Calculate population which can be served.

$$\frac{\text{Total Bed Area, Sq ft}}{\text{Area per capita, sq ft/capita}} = \frac{6,400}{2.0} \qquad \underline{\text{3,200 persons}}$$

Typical Performance Evaluation

The performance of sludge drying beds is different from one location to the next. Sludge drying bed performance is affected by weather, sludge characteristics, system design (including depth of fill), chemical conditioning, and drying time. Typical performance in terms of solids loading rate and moisture content of dried sludge are as follows for open and covered beds.

	Open beds	Covered beds
Solids Loading Rate, lb/yr/sq ft	up to 25	up to 40
Moisture content of dried sludge, percent	50 - 60	50 - 60

Process Control

Process control practices are described in detail in Reference 4.

Maintenance Considerations

The features of a good maintenance program are:

1. Drying beds inspected every few days with particular attention given to potential odor and insect problems.
2. Beds levelled and raked prior to each sludge application.
3. Sand depth checked regularly for losses of sand during sludge removal from beds.
4. Makeup sand added when sand depth decreases to 3 or 4 inches.
5. Weed growth on beds controlled by use of weed killer or hand pulling.
6. Fly control by destruction of breeding and use of traps and poisons.
7. Drainage system inspected and maintained on a routine basis.
8. Sludge lines drained after use in winter to prevent freezing.
9. If earth beds are used, grass and other vegetation cut regularly.
10. Stop logs kept well maintained to minimize leakage from vehicular access cutouts in drying bed walls.

Records

Recommended sampling and laboratory tests are shown on Figure 35-1.

Other operating records should include:

1. Time and date sludge is applied to each drying bed.
2. Number of days before sludge is dry enough for removal.
3. Volume of sludge removed from beds.
4. Date makeup sand is required for each bed and quantity of makeup required.

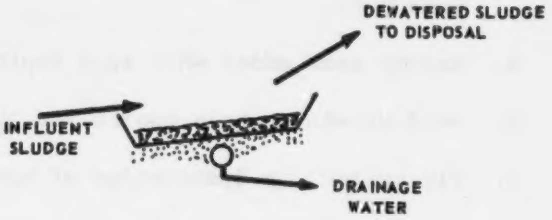
Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor sludge drying beds:

1. Analytical balance
2. Clinical centrifuge with graduated tubes
3. BOD incubator
4. Drying oven
5. Imhoff Cones

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

DRYING BEDS



SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TOTAL SOLIDS	ALL	W	I	G	H
TOTAL SOLIDS	ALL	W	D	G	P
BOD_5	ALL	M	Dr	G	P
TOTAL SOLIDS	ALL	M	Dr	G	P

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT SLUDGE
D = DEWATERED SLUDGE
Dr = DRAINAGE WATER

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 35-1

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, miscellaneous furniture, etc., and should be referred to for any detailed questions.

Sampling Procedures

Samples of the influent sludge may be obtained through valves provided in the sludge lines. Samples of the dried sludge cake can be obtained directly from the drying bed. Samples of the drainage water should be collected from valves in the drain lines or at the recycle pumping station. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used.

Sidestreams

The only sidestream is the drainage water. This water is normally returned to the raw sewage flow to the plant or to the plant headworks.

The flow from the drainage piping consists primarily of the initial percolation of water from the sludge plus some periodic percolation after rain storms (assuming open beds).

Process Checklist-Drying Beds

1. What are the dimensions of the drying beds? ____________________
   How many separate drying bed compartments are there? ____________
2. Are the sludges digested before they are applied to the drying bed?
   ( ) Yes ( ) No
3. What type of sludges are applied to the drying beds (digested primary, waste activated, combination, etc.) ____________________?
4. What is the volume of sludge flow applied to the drying beds ____________________ gallons/day average?
5. What is the design sludge flow ______________ gallons/day average?
6. What is the solids concentration in the sludge applied to the drying beds? __________________%
7. What is the solids loading rate ______________________ lbs/yr/sq ft?
8. What is the population served by the treatment plant? ____________
9. What is the drying area provided, based on sq ft/capita?____________
10. What is the solids concentration in the dewatered sludge? __________
11. What is the typical drying time required? ________________ days
12. Are there odor problems? ( ) Yes ( ) No
13. Are there problems with flies or other insects? ( ) Yes ( ) No
14. Are there problems with weed growth? ( ) Yes ( ) No
15. Is there an underdrain system? ( ) Yes ( ) No
16. Are there provisions for the return of drainage waters to the plant?
    ( ) Yes ( ) No
17. What is the typical sand depth? ___________ inches
18. Are there any beds with sand depths less than 3 or 4 inches?
    ( ) Yes ( ) No
19. Are vehicles and equipment operated on permanent vehicle treadways or on planks or plywood laid on top of the beds? ( ) Yes ( ) No
20. Are splash plates or diffusion devices in place when sludge is applied to the beds? ( ) Yes ( ) No
21. Are partitions between and around the bed tight so that sludge will not flow from one compartment to another nor outside the beds?
    ( ) Yes ( ) No

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).
2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).
3. State of Virginia O&M inspection form.
4. Ettlich, W.F., et al, Operations Manual - Sludge Handling and Conditioning, US EPA Report 430/9-78-002.

36. DRYING LAGOONS

Process Description

Sludge lagoons are similar to sand beds in that sludge is periodically drawn from a digester, placed in the lagoon, removed after a period of drying, and the cycle repeated. Drying lagoons do not have an underdrain system. Most of the drying is by decanting supernatant liquor and by evaporation. Plastic or rubber fabrics may be used as a bottom lining, or they may be natural earth basins. Supernatant liquor and rainwater drain off points are usually provided, with the drain off liquid returned to the plant for further processing.

Typical Design Considerations

The loading rate to the lagoon is expressed as pounds of dry solids applied per year per cubic foot of lagoon capacity. This is calculated as follows:

1. Determine lagoon volume. The plant construction drawings may contain this information or it may be possible to simply measure the lagoons.

   Length = 100 ft
   Width = 25 ft
   Depth = 2 ft
   Number of lagoons = 2
   Total volume = Length x Width x Depth x Number of lagoons
   = 100 x 25 x 2 x 2
   = 10,000 cu ft

2. Determine sludge flow to lagoon from plant records.

   Daily flow = 150 gal/day
   Yearly flow = Daily flow x 365 (or weekly flow x 52)
   = 55,000 gal/yr

3. Determine sludge solids concentration

   Concentration $= \frac{\text{Weight of dry sludge}}{\text{Weight of wet sludge}}$

   $= 0.5 \text{ lb} = \frac{0.05 \text{ lb}}{10 \text{ lb}} = 0.05$

4. Determine weight of sludge applied to lagoon per year.

   Weight = yearly flow x concentration x 8.34
   = 55,000 x 0.05 x 8.34
   = 23,000 lb/yr

5. Calculate solids loading rate.

   Solids loading rate $= \frac{\text{Weight of sludge applied per year}}{\text{Volume of lagoon}}$

   $= \frac{23{,}000 \text{ lb/yr}}{10{,}000 \text{ cu ft}}$

   = 2.3 lb/yr/cu ft

Typical design criteria are 2.2-2.4 lb/yr/cu ft of lagoon capacity.

Typical Performance Evaluations

Drying time for sludge applied to a depth of 15 inches or less is 3 to 5 months. This figure is highly dependent on weather conditions. The sludge is usually dried to 40 to 60 percent solids.

Process Control

Sludge depth should not exceed 15 inches after excess supernatant has been drawn off. Unless the lagoon is situated in an arid climate, depths of over 15 inches will require excessive drying time.

The operator should promptly remove supernatant liquor and rainwater so that the sludge cake is exposed to oxygen in the air and can dry rapidly. Supernatant is normally returned to the main plant treatment processes.

Sludge will generally not dewater in any reasonable period of time. Dried sludge may be removed with a front-end loader in 3 to 5 months. When sludge is to be used for soil conditioning, it may be stored for added drying before use. One operational approach uses a 3-year cycle in which the lagoon is loaded for 1 year, dries for 18 months, is cleaned, and allowed to rest for 6 months.

Maintenance Considerations

The features of a good maintenance program are:

1. Broken dikes repaired as required.
2. Excess water from rain or snow decanted to facilitate drying.
3. Weeds kept to a minimum.
4. Lagoons checked for odor and insect problems.
5. Lagoons leveled and weeds removed prior to each sludge application.
6. Sludge application lines and valves regularly inspected and maintained.
7. Sludge lines drained to prevent breakage from freezing in winter.

Records

Monitoring of sludge lagoons generally consists of visual inspection by the plant operator. However, records may be kept on the sludge loading, percent solids, quantity, depth, date, drying time and weather conditions. This will provide the operator with the information necessary to determine the optimal time of sludge removal from the lagoon by comparing sludge moisture content with time of drying for particular climatic conditions.

Laboratory Equipment

The laboratory should include the following equipment as a minimum to monitor sludge drying lagoons.

1. Analytical balance
2. Drying oven

Sampling Procedures

Samples of the influent sludge may be obtained through valves provided in the sludge lines or directed from the lagoon. Samples of dried sludge can be obtained directly from the lagoon. Samples of supernatant can be collected from valves in the draw-off lines. The sample collector and containers should be clean. A wide mouth sample collector of at least 2 inches should be used.

Sidestreams

The only sidestream is the supernatant or rainwater draw-off. This water is normally returned to the raw sewage flow for further processing.

Processing Checklist - Drying Lagoon

1. What are the dimensions of the lagoon ________________? How many lagoons are there ____________?
2. What is the volume of sludge applied to the lagoons __________gal/day avg.
3. What type of sludge is applied ________________?
4. What is the design sludge application rate _____________gal/day avg.
5. What is the solids loading rate ___________lb/yr/cu ft?
6. What is the typical drying time required _________months?
7. What is the solids concentration in the dried sludge ___________%?
8. Are insects a problem? ( ) Yes ( ) No
9. Is weed growth a problem? ( ) Yes ( ) No
10. Are partitions between and around the lagoons tight so that sludge will not flow from one compartment to another? ( ) Yes ( ) No
11. Are there provisions for supernatant draw-off? ( ) Yes ( ) No
12. Are there signs of overload? ( ) Yes ( ) No
13. Does the sampling program meet the recommendations? ( ) Yes ( ) No
14. Is the laboratory equipped for the necessary analyses? ( ) Yes ( ) No
15. What are the most common problems the operator has had with the process?

____
____
____
____
____

References

1. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

2. Guarino, C.F., et al, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation (1976).

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

37. INCINERATION - MULTIPLE HEARTH

A multiple hearth furnace consists of a circular steel shell surrounding a number of solid refractory hearths and a central rotating shaft to which rabble arms are attached. The dewatered sludge enters at the top through a flapgate and proceeds downward through the furnace from hearth to hearth, moved by the rotary action of the rabble arms. The hearths are constructed of high heat duty fire brick and special fire brick shapes. Since the furnace may operate at temperatures up to 2,000°F, the central shaft and rabble arms are cooled by air supplied from a blower. The hot air may be discharged to atmosphere or returned to the bottom hearth of the furnace as preheated air for combustion purposes.

Periodically the ash produced by incineration must be removed from the furnace. There are two options for handling ash from the furnace. One is to provide a storage hopper and unload dry ash to trucks. The other is to add water and handle ash as a slurry with the slurry being pumped to a lagoon.

Typical Design Considerations

Loading rates for several types of sludge are shown in Table 37-1.

TABLE 37-1. MULTIPLE HEARTH FURNACE LOADING RATES

Type of sludge	Solids, %	Volatile solids, %	Chemical concentration,* mg/l	Typical wet sludge loading rate,** lb/hr/sq ft
1. Primary	30	60	N/A	7.0-12.0
2. Primary + $FeCl_3$	16	47	20	6.0-10.0
3. Primary + low lime	35	45	298	8.0-12.0
4. Primary + WAS	16	69	N/A	6.0-10.0
5. Primary + (WAS + $FeCl_3$)	20	54	20	6.5-11.0
6. (Primary + $FeCl_3$ + WAS	16	53	20	6.0-10.0
7. WAS	16	80	N/A	6.0-10.0
8. WAS + $FeCl_3$	16	50	20	6.0-10.0
9. Digested primary	30	43	N/A	7.0-12.0

* Assumes no dewatering chemicals.

** Low number is applicable to small plants, high number is applicable to large plants.

The data in this table developed from manufacturers' information.

The following sample calculations are examples of process control equations.

1. **Excess Air** is the amount of air required beyond the theoretical air requirements for complete combustion. This parameter is expressed as a percentage of the theoretical air required.

   Sample calculation for excess air:

$$\text{excess air} = \frac{(\text{actual air rate-theoretical rate}) \times 100}{\text{theoretical air rate}}$$

$$= \frac{(1{,}500 - 1{,}000) \times 100}{1{,}000}$$

$$= 50\%$$

2. **Sludge loading rate** is the weight of wet sludge fed to the reactor per square foot of reactor bed area per hour (lb/sq ft/hr).

   Sample calculation for loading rate:

$$\text{loading rate} = \frac{\text{lb sludge/hr}}{\frac{\pi d^2}{4}} \quad \frac{100}{\%\ \text{moisture content}}$$

$$= \frac{440}{\frac{3.14\ (20)^2}{4}} \quad \frac{100}{20}$$

$$= 7.01\ \text{lb/sq ft/hr}$$

3. **Solids concentration** is the weight of solids per unit weight of sludge. It is calculated as follows:

$$\text{concentration} = \frac{\text{weight of dry sludge solids} \times 100}{\text{weight of wet sludge}}$$

$$= \frac{25 \times 100}{120}$$

$$= 20.8\%$$

4. **Moisture content** is the amount of water per unit weight of sludge. The moisture content is expressed as a percentage of the total weight of the wet sludge. This parameter is equal to 100 minus the percent solids concentration or can be computed as follows:

$$\text{moisture content} = \frac{(\text{weight of wet solids} - \text{weight of dry solids}) \times 100}{\text{weight of wet solids}}$$

$$= \frac{(120 - 25) \times 100}{120}$$

$$= 79.2\%$$

Typical Performance Evaluation

The volume reduction by sludge incineration is over 90 percent when compared to the volume of dewatered sludge. The ash from the incineration process is free of pesticides, viruses and pathogens. Metals will be converted to the less soluble oxide form or volatilized. The ash can be transported in the dry state to appropriate landfill sites or used as a soil conditioner.

The critical sidestream treatment requirement is the flue gas treatment. The scrubbed gases should meet the most stringent air quality requirements. A comparison of scrubbed gas quality with Southern California Air Pollution Control District Rules is shown in Table 37-2.

TABLE 37-2. STACK SAMPLING RESULTS, MULTIPLE HEARTH INCINERATOR WITH COMBINATION LIME-ORGANIC SOLIDS FEED

	Test A	Test B	Test C	SCAPCD rules
Combustion contaminants, grains/SCFM at 12% CO_2	.026	.016	.014	0.1 (Rule 473)
Oxides of sulfur: (as SO_2), ppm	2.2	2.3	3.2	2000 (Rule 53)
Oxides of nitrogen (as NO_2), ppm	52	65	-	300 (Rule 474)

Tests made at South Lake Tahoe Public Utility District, CA, on November 10, 1970.

Process Control

Process control furnaces can be complex. A complete discussion is given in Reference 3.

Maintenance Management

A good preventive maintenance program will reduce breakdowns which could be costly and dangerous for operating personnel. A good preventative maintenance program is very important for an incinerator because of the large drives and the need to minimize incinerator shutdowns. The following are the major elements which should receive regular attention.

1. Drives and gear reducers
2. Chains and sprockets
3. Burners
4. Air blowers
5. Sludge conveying equipment
6. Ash conveying equipment

7. Furnace seals
8. Draft controller
9. Temperature controllers
10. Any standby engine drives or generators
11. Scrubber

Records

Records keeping includes the process control tests shown in Figure 37-1 and historical data. Historical data include the tons of sludge incinerated each year, the fuel consumed, and maintenance records. Maintenance records are extremely important since equipment lives with multiple hearth furnaces are accurately predictable. Knowing the last date of equipment replacement the operator can predict the next time that furnace will need to be shut down for equipment overhaul or replacement.

Laboratory Equipment

Testing equipment for incineration monitoring is quite simple. Most continuous monitoring is accomplished by automatic equipment which is part of the total system. Additional equipment items include a drying oven and balance scales to determine solids contents.

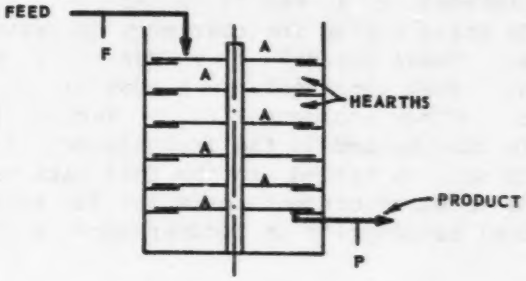
Sampling Procedures

Sampling for many parameters is automatic. Sludge volatile solids and moisture contents of material fed to the incinerator require a simple drawing off of sludge from the feed line or from the preceeding unit process (storage or dewatering). There are no special sample preservation measures to be taken other than capping the sample to prevent a change in moisture content.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

INCINERATION

(MULTIPLE HEARTH)



SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TEMPERATURE		Mn	A	Mn	P
TOTAL VOLATILE SOLIDS		1/D[1]	F P	G	P
TOTAL SOLIDS		1/D[1]	F P	G	P

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

F = FEED
P = PRODUCT
A = FURNACE ATMOSPHERE (AT EACH HEARTH)

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. WHEN FURNACE IS OPERATING

Figure 37-1

Process Checklist - Multiple Hearth

1. Are complete records kept on the following items?
    a. Hearth temperatures (each shift) ( ) Yes ( ) No
    b. Maintenance work accomplished ( ) Yes ( ) No
    c. Schedule of upcoming maintenance ( ) Yes ( ) No
    d. Fuel consumption (daily) ( ) Yes ( ) No
    e. Power consumption (daily) ( ) Yes ( ) No
    f. Sludge moisture content (each shift) ( ) Yes ( ) No
    g. Sludge volatile solids content (daily) ( ) Yes ( ) No
2. Does operator have a planned procedure for slowly shutting down the process? ( ) Yes ( ) No
3. Is there a plan for emergency operation for:
    a. Power outage? ( ) Yes ( ) No
    b. Fuel shortage? ( ) Yes ( ) No
    c. Other accidents? ( ) Yes ( ) No
4. Is scum burned in the incinerator? ( ) Yes ( ) No
5. If scum is burned, is the feed rate regulated? ( ) Yes ( ) No
6. Is moisture content optimized for minimum total cost of dewatering and fuel consumption in incinerator? ( ) Yes ( ) No

References

1. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 14th Edition 1975, Washington, D.C. 20036.
2. Unterberg, W., et al, Computerized Design and Cost Estimation for Multiple Hearth Sludge Incinerators US EPA, 17070 EBP 07/71.
3. Ettlich, W.F. et al, Operations Manual Sludge Handling and Conditioning, U.S. EPA, Office of Water Program Operations, Washington, D.C., 430/9-78-002, February 1978.

38. INCINERATION - FLUIDIZED BED

The fluidized bed incinerator is a vertical cylindrical vessel with a grid in the lower section to support a sand bed. Dewatered sludge is injected above the grid and combustion air flows upward to fluidize the mixture of hot sand and sludge. Supplemental fuel can be supplied by burners above or below the grid. In essence, the reactor is a single chamber unit were both moisture evaporation and combustion occur. Ash is carried out the top with combustion exhaust and is removed by air pollution control devices. A fluidized bed incinerator does not need to be operated continuously since the sand bed stores heat, thus reducing furnace reheating requirements.

Typical Design Considerations

Typical loading rates for various types of sludge are shown on Table 38-1. The loading rates are a function of the moisture content of the feed sludge.

TABLE 38-1 LOADING RATES

Type of sludge	Solids, %	Volatile solids, %	Chemical concentration,* mg/l	Wet sludge loading rate, lb/hr/sq ft
1. Primary	30	60	N/A	14
2. Primary + $FeCl_3$	16	47	20	6.8
3. Primary + low lime	35	45	298	18
4. Primary + WAS	16	69	N/A	6.8
5. Primary + (WAS + $FeCl_3$)	20	54	20	8.4
6. (Primary + $FeCl_3$ + WAS	16	53	20	6.8
7. WAS	16	80	N/A	6.8
8. WAS + $FeCl_3$	16	50	20	6.8
9. Digested primary	30	43	N/A	14

* Assumes no dewatering chemicals.

The following are sample design calculations.

1. Excess air is the amount of air required beyond the theoretical air requirements for complete combustion. This parameter is expressed as a percentage of the theoretical air required.

   Sample calculation for excess air: Assume 1,200 SCFM actual, and 1,000 SCFM theoretical

$$\text{Excess air} = \frac{\text{(actual air rate-theoretical rate) x 100}}{\text{theoretical air rate}}$$

$$= \frac{(1{,}200 - 1{,}000) \text{ x } 100}{1{,}000} = 20\%$$

2. Sludge loading rate is the weight of wet sludge fed to the reactor per square foot of reactor bed area per hour (lb/sq ft/hr).

   Sample loading rate: Assume 20 foot diameter reactor, 20 percent feed sludge moisture content and 440 pounds dry sludge per hour

$$\text{Loading rate} = \frac{\text{(lb dry sludge/hr) (100)}}{\text{(\% moisture content) (area)}}$$

$$= \frac{440 \text{ x } 100}{20\% \text{ x } \dfrac{3.14\ (20)^2}{4}}$$

$$= 7.01 \text{ lb/sq ft/hr}$$

3. Solids concentration is the weight of solids per unit weight of sludge. It is calculated as follows:

   Assume 120 lb wet sludge with 25 lb of dry solids.

$$\text{Concentration} = \frac{\text{weight of dry sludge solids x 100}}{\text{weight of wet sludge}}$$

$$= \frac{25 \text{ x } 100}{120}$$

$$= 20.8\%$$

4. Moisture content is the amount of water per unit weight of sludge. The moisture content is expressed as a percentage of the total weight of the wet sludge. This parameter is equal to 100 minus the percent solids concentration or can be computed as follows:

   Same assumptions as paragraph 3.

$$\text{moisture content} = \frac{\text{(weight of wet solids)-(weight of dry solids x 100}}{\text{weight of wet solids}}$$

$$= \frac{(120 - 25) \text{ x } 100}{120}$$

$$= 79.2\%$$

Performance

The measure of furnace performance is the stack gas quality. The gas quality is measured in terms of particulates, metals, gaseous pollutants, and organic compounds. The scrubber is designed to remove particulates with the ash. Most metals appear as oxides in the particulates removed by the scrubber. Lead and mercury vaporize and will appear in the stack gas. Carbon monoxide in the stack gas is a sign of improper design or operation.

Process Control

The fluid bed furnace is furnished with a semi-automatic process control system and a mechanical/electrical protection system, which free the operator from continuous supervision. The process is maintained in balance at the required excess air and operating temperatures by normal adjustments in air rate and sludge feed rate, and automatic control of auxiliary fuel rate. The process parameters and physical conditions are kept in check by means of a multipoint alarm system which warns the operator of impending imbalances in the process or mechanical equipment.

A variety of process controls are described in Reference 4.

Maintenance Considerations

Sand from the reactor bed is gradually lost through the exhuast as individual sand particles are gradually worn into finer and finer particles. When it has been determined that the bed level is getting low, proceed as follows:

1. Bed temperature should be at least 1,400°F before any sand is added to the reactor bed. This is to avoid cooling the bed below 1,150°F, and being forced to light the preheat burner.
2. Be sure that the fluidizing blower is completely stopped.
3. Remove the blind flange on the sand feed nozzle. Attach sand feed chute.
4. Add sand in 10 bag batches. If more than 10-100 lb bags are required, replace the blind flange on the same feed nozzle and reheat the bed to 1,400°F before adding second 10 bag batch.

There may be slight leakage of sand down into the windbox. About once a month (when the reactor is not operating), open the windbox manhole and rake out any accumulation.

Occasionally a carbon deposit may form near the tip of the fuel burner. If this happens, fuel flow to the bed will be restricted. When the reactor is shutdown, clean the burner. If available, a slight flow of compressed air will aid inserting the gun back in the bed.

From time to time, check that the nut on the packing gland is just tight enough to prevent loss of cooling air.

At times this pressure tap pipe may become partially plugged. Refer to manufacturer's manual for cleaning instructions.

Keep gasketed surfaces on the reactor tight to avoid a fly ash nuisance.

Records

Records keeping includes the process control tests as well as historical data and maintenance records.

The analyses required for furnace monitoring and their frequency are shown on Table 38-2 for each monitoring point identified on Figure 38-1.

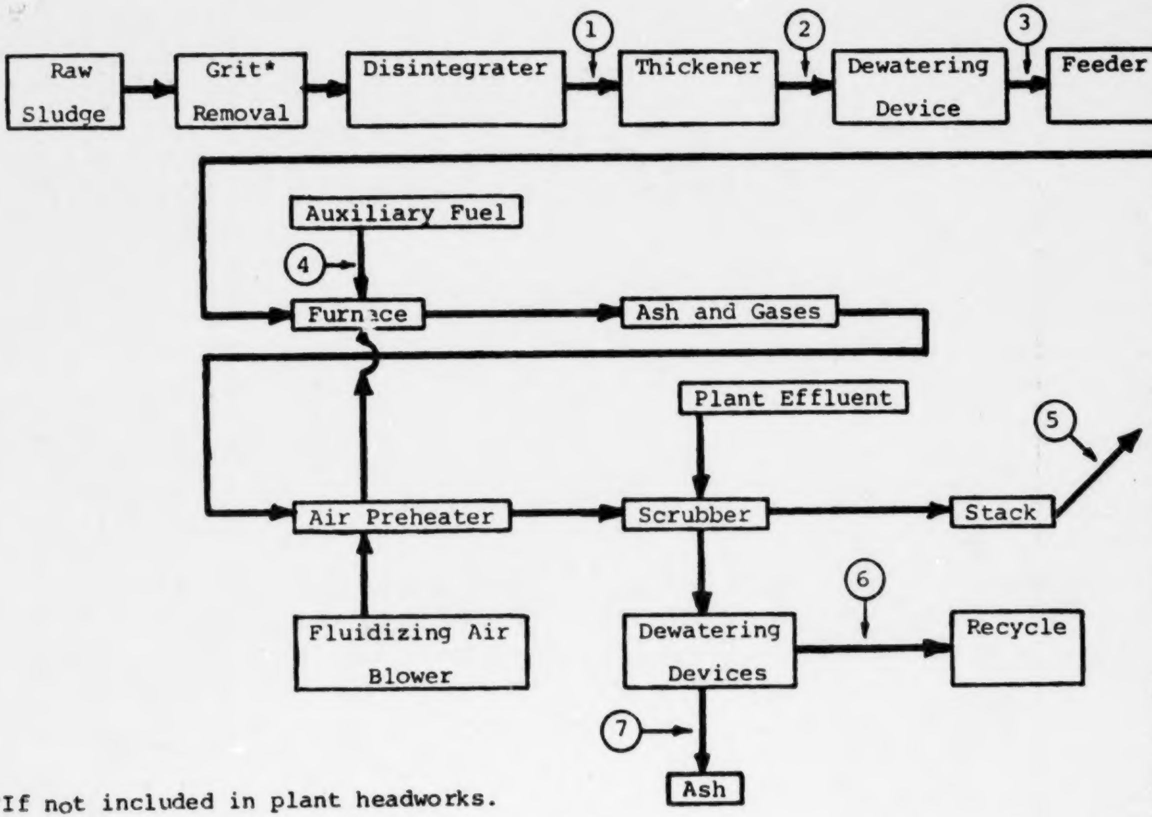
TABLE 38-2. MONITORING

Monitoring point	Analysis	Frequency
1	Solids content	Weekly
2	Solids content	Weekly
3	Solids content	Weekly
3	Volatile solids	Weekly
4	Fuel quantity	Continuous
5	Oxygen content	Continuous
5	Particulate concentration	Weekly
5	Carbon monoxide	Monthly
5	Lead	Semiannual
5	Mercury	Semiannual
5	Hydrogen chloride	Semiannual
5	Sulfur dioxide	Semiannual
5	Oxides of nitrogen	Semiannual
6	BOD_5	Weekly
6	Suspended solids	Weekly
7	Metals content	Semiannual*
7	Moisture content	Weekly

* If ash used for soil conditioner.

Laboratory Equipment

Testing equipment for incineration monitoring is quite simple. Most continuous monitoring is accomplished by automatic equipment which is part of the total system. Additional equipment items include a drying oven and balance scales to determine solids contents.


Raw Sludge
Grit* Removal
Disintegrater
Thickener
Dewatering Device
Feeder
1
2
3
Auxiliary Fuel
4
Furnace
Ash and Gases
Plant Effluent
5
Air Preheater
Scrubber
Stack
Fluidizing Air Blower
Dewatering Devices
Recycle
6
7
Ash

*If not included in plant headworks.

Figure 38.1. Fluidized bed furnace system monitoring points.

Sampling Procedures

Sampling for many parameters is automatic. Sludge volatile solids and moisture contents of material fed to the incinerator require a simple drawing off of sludge from the feed line or from the preceeding unit process (storage or dewatering). There are no special sample preservation measures to be taken other than capping the sample to prevent a change in moisture content.

Process Checklist - Multiple Hearth and Fluidized Bed Furnaces

1. Are complete records kept on the following items?
   a. Temperature (each shift) ( ) Yes ( ) No
   b. Maintenance work accomplished ( ) Yes ( ) No
   c. Schedule of upcoming maintenance ( ) Yes ( ) No
   d. Fuel consumption (daily) ( ) Yes ( ) No
   e. Power consumption (daily) ( ) Yes ( ) No
   f. Sludge moisture content (each shift) ( ) Yes ( ) No
   g. Sludge volatile solids content (daily) ( ) Yes ( ) No
2. Does operator have a planned procedure for slowly shutting down the process? ( ) Yes ( ) No
3. Is there a plan for emergency operation for:
   a. Power outage? ( ) Yes ( ) No
   b. Fuel shortage? ( ) Yes ( ) No
   c. Other accidents? ( ) Yes ( ) No
4. Is scum burned in the incinerator? ( ) Yes ( ) No
5. If scum is burned, is the feed rate regulated? ( ) Yes ( ) No
6. Is moisture content optimized for minimum total cost of dewatering and fuel consumption in incinerator? ( ) Yes ( ) No

References

1. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 14th Edition, 1975, Washington, D.C.

2. Dorr-Oliver FS Disposal System Operating Instructions.

3. Copeland Systems Operating Instructions.

4. Ettlich, W.F. et al, Operations Manual Sludge Handling and Conditioning, U.S. EPA, Office of Water Program Operations, Washington, D.C., 430/9-78-002, February 1978.

39. LIME RECALCINING

Process Description

Lime often is used as a coagulant either as a tertiary step or ahead of the primary clarifier for removal of phosphorus from wastewaters. In recalcining, the dewatered calcium-containing sludge is heated to about 1,850°F. This drives off water and carbon dioxide leaving calcium oxide (or quicklime).

In municipal wastewater treatment, multiple hearth furnaces have been used for recalcining. Although fluidized bed furnaces have been used for industrial and water treatment purposes, these furnaces have not been used for municipal wastewater recalcining. Prior to the recalcining step centrifuges can be used to separate the phophate-rich lime from the inert solids also removed by the lime.

The recalcined lime usually is discharged into a hammermill to break up any lumps that have formed in the furnace. The material is forced against a grinding plate by the rotating hammers. The lumps are broken up until they are small enough to fit through the openings in a metal screen. The material then goes to a thermal disc cooler. When cool, the reclacined lime is stored and mixed with fresh lime before reuse.

Typical Design Considerations

The capacity of a lime recalcining multiple hearth furnace depends on solids loading per unit of hearth surface area. Sizing also depends on the nature of the sludge cake, including moisture, volatile solids, inerts content, and heat value. A loading rate of 7 to 12 lb wet sludge/hr/sq ft of hearth is common. The feed sludge should have a moisture content of less than 50 percent.

Typical Performance Evaluation

Proper operation of the recalcining furnace should produce a recalcined lime which will meet the AWWA standard for quicklime (CaO). Typically, the lime should have a CaO content of at least 60 to 70 percent and should slake readily in standard slakers. Typical loading rates are about 1 lb dry solids per square foot of furnace hearth area.

Process Control

There are two important characteristics of the recalcined lime which must be controlled.

1. Activity, and
2. Slaking characteristics

Recalcined lime must be classified according to the AWWA Standard for quicklime (CaO) and hydrated lime ($Ca(OH)_2$) (AWWA B202-65):

	Time for 40° rise in temp., (min)	Time for complete reaction (min)
High-reactive, soft burned lime	3 or less	10
Medium-reactive, medium burned lime	3-6	20
Low-reactive, hard burned lime	More than 6	More than 20

It is possible to produce quicklime with the same CaO content, but with very different slaking properties.

The most important variables in the operation of the recalcining furnace are temperature and feed rate. These are addressed in detail in Reference 1. The rabble arm rate in a multiple hearth furnace has little effect on recalcined lime if it is within 1.5 to 2 rpm.

Maintenance Considerations

The features of a good maintenance program are:

1. Burner controls been checked and calibrated within a year.
2. Temperature controllers maintain the hearth temperatures near set point.
3. Refractory should be inspected on a regular basis.
4. Area housekeeping around the furnace or where there are spills of lime or buildups of lime dust.
5. Interior of the scrubber been inspected within a year.
6. Check sand level in the upper shaft seal.

Records

Recommended sampling and laboratory tests are shown in Figure 39-1.

Operating records should also include:

1. A method for determining the feed rate to the furnace.
2. Quantity of lime recovered.

Laboratory Equipment

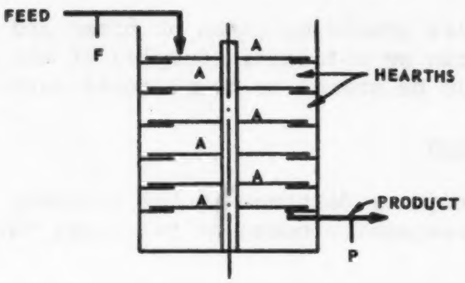
The laboratory equipment should include the following minimum equipment:

1. Furnace oxygen analyzer
2. Equipment and procedures for analyzing CaO content

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

RECALCINATION

(MULTIPLE HEARTH)



SUGGESTED MINIMUM

OPTIONAL

	PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
TEMPERATURE	ALL	Mn[1]	A	Mn	P
CALCIUM CONTENT (CaO)	ALL	2[1]	P	G	P C
MOISTURE CONTENT	ALL	1/W	F	G	P

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

F = FEED
P = PRODUCT
A = FURNACE ATMOSPHERE (AT EACH HEARTH)

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. WHEN FURNACE IS OPERATING
2. SPOT CHECK

Figure 39-1.

3. Drying oven
4. Analytical balance
5. Normal glassware and accessories

The EPA report "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" contains very detailed information on glassware, chemicals, and miscellaneous furniture and should be referred to for any detailed questions.

Sampling Procedures

Samples should be taken at times and locations where representative samples can be obtained. Samples of hot materials should be handled carefully and should be stored in metal containers.

Sidestreams

The major sidestream is the scrubber water which can be returned to the liquid treatment process or to sludge thickeners.

Process Checklist - Lime Recalcining

1. What is required lime dosage in the liquid process __________lb/mg average?
2. What is average flow through lime treatment______________ mg/day?
3. Calculate approximate average lime recalciner feed rate, item 1 x item 2 = ____________________ lb/day
4. What is rated capacity of furnace, _____________lb/day?
5. Check feed rate at the current setting, _________________lb/hr.
6. Is the recalcined lime CaO content checked as a regular process control parameter? ( ) Yes ( ) No
7. Is feed sludge moisture content checked on a regular basis? ( ) Yes ( ) No
8. Is there a method to selectively waste approximately 25% of the lighter fractions of the feed sludge in order to control inerts? ( ) Yes ( ) No
9. Are hearth temperatures logged and are they adequately controlled? ( ) Yes ( ) No
10. Is the lime grinder and cooler in operation?( ) Yes ( ) No
11. Is the maintenance program adequate? ( ) Yes ( ) No
12. Have the burners been calibrated within a year? ( ) Yes ( ) No
13. Are the alarms and shutdowns adequate? ( ) Yes ( ) No
    Are they checked regularly? ( ) Yes ( ) No
14. Are operating records adequate? ( ) Yes ( ) No
15. Is the laboratory and operational office equipped for the necessary analyses? ( ) Yes ( ) No
16. What spare parts are stocked? ____
    ____
    ____
17. What are the most common problems the operator has had with the process?
    ____
    ____
    ____
    ____

References

1. Culp, G.L. and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, EPA 430/9-78-001.

2. Culp, Russell L., and Culp, Gordon L., Advanced Wastewater Treatment, Van Nostrand Reinhold Co., 1971.

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Culp/Wesner/Culp, Operation and Maintenance Manual, Water Factory 21, Orange County water District", (June, 1974).

6. CH2M-Hill, Operation and Maintenance Manual for Wastewater Reclamation Facility, South Tahoe PUD, (1976).

7. Culp, R.L., et al, Advanced Wastewater Treatment as Practiced at South Tahoe, U.S. Environmental Protection Agency, Project 17010 ELQ (WPRD 52-01-67), August, 1971.

40. GRANULAR CARBON REGENERATION

Process Description

Granular activated carbon removes detergents, insecticides, herbicides, and various organic substances which contribute to the taste, odor and color of the wastewater. The carbon eventually becomes saturated and loses its ability to further adsorb organic materials. The carbon nearest to the inlet of the contactor becomes saturated or exhausted first.

The purpose of the regeneration process is to restore the adsorptive capacity of the granular carbon. Regeneration is accomplished by heating the carbon to temperatures in excess of 1,500°F. The heat vaporizes and drives off the adsorbed impurities restoring the carbon essentially to its original activity. Regeneration is carried out most effectively in multiple hearth furnaces.

The carbon is dewatered prior to feed to the furnace and the hot regenerated carbon cooled in a quench tank upon discharge from the furnace. The regenerated carbon is then washed to remove fines.

Typical Design Considerations

Experience has shown that carbon dewatering can be accomplished by gravity in about 1 hour with properly designed dewatering bins. The dewatered carbon should have a moisture content of 40 to 45 percent. The dewatering bin should be sized for a reasonable quantity of carbon, typically, a days feed to the furnace.

Typically, furnace loadings are based on the hearth area, with an average being 50 to 70 lbs per day of carbon per square foot of total hearth for a 6 hearth furnace. A 6-hearth, 54-inch inside diameter furnace is rated for approximately 6,000 lb of carbon per day. A regeneration furnace can be operated over a wide range of carbon feed, and can be turned down by a ratio of 6:1, however it is usually better to operate at a constant rate if possible.

Typical Performance Evaluation

The performance of the carbon regeneration process is best determined by apparent density (AD) tests of the regenerated carbon. The AD of new carbon is about 0.48. As carbon becomes saturated with adsorbed organics, the AD increases to over 0.50. If properly regenerated, the AD will return to 0.48.

If the AD is greater than 0.49, the carbon is not being heated enough to volatilize a sufficient quantity of organic material; conversely if the AD is less than 0.48, the carbon is being overheated and burned in the furnace.

Process Control

The regeneration process consists of several steps as the carbon passes through the furnace.

1. Drying
2. Decomposition or pyrolyzing of the adsorbed organic matter.
3. Gasification of the organics and reactivation of the carbon pore structure.

These and other process considerations are discussed in Reference 1.

Maintenance Considerations

The features of a good maintenance program that the inspector should look for are:

1. Burner controls checked and calibrated within a year.
2. Temperature controllers maintain the hearth temperatures near set point.
3. Refractory appears in good condition.
4. Dewatering screens cleaned regularly.
5. Area around the furnace cleaned.
6. Interior of the scrubber been inspected within a year.
7. Sand level in the upper shaft seal.

Records

Recommended sampling and laboratory tests are shown in Figure 40-1.

Operating records should also include:

1. A written log of carbon movements and regeneration scheduling.
2. A method to determine the carbon feed rate to the furnace.
3. A method to determine carbon losses and make-up carbon additions.

Laboratory Equipment

The laboratory equipment should include the following minimum equipment:

1. Graduated cylinder, drying over, balance, and shaker for running apparent density test.
2. Carbon grinder and other equipment for iodine number test.
3. Furnace oxygen analyzer.

Sampling Procedures

Samples should be taken to assure that they are representative. Most of the carbon sampling involves dipping out scoops of the material. Hot carbon should be handled with care to avoid injury and should be stored in metal containers.

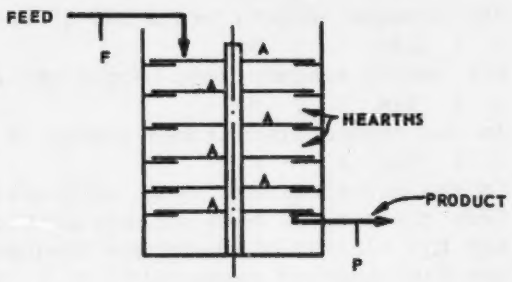
Sidestreams

Sidestream flows consist of carbon transport water, dewatering tank drainage, defining water, quench tank overflow, and scrubber water. These sidestream flows are a very small percent of the liquid process flow and may be returned to the primary or secondary treatment process.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

CARBON REGENERATION

(MULTIPLE HEARTH)



		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TEMPERATURE	ALL	Mn[1]	A	Mn	P
	OXYGEN CONTENT	ALL	1/D[1]	A	G	P
	PERCENT ASH	ALL	1/D[1]	P	G	P
	APPARENT DENSITY	ALL	1/H[1]	P	G	P
	IODINE NUMBER	ALL	1/D	F P	G	H
	APPARENT DENSITY	ALL	1/D[1]	F	G	H
OPTIONAL						

A. TEST FREQUENCY

H = HOUR	M = MONTH
D = DAY	R = RECORD CONTINUOUSLY
W = WEEK	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

F = FEED
P = PRODUCT
A = FURNACE ATMOSPHERE (AT EACH HEARTH)

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. WHEN FURNACE IS OPERATING
2. SPOT CHECK

Figure 40-1

Process Checklist - Granular Carbon Regeneration

1. What is required carbon dosage in the liquid process __________lb/mg average?
2. What is average flow through carbon _______________ mg/day?
3. Calculate approximate average carbon regeneration rate, item 1 x item 2 = _______________________ lb/day
4. What is rated regeneration capacity of furnace, _______________lb/day?
5. Check feed screw rate at the current setting, __________________lb/hr.
6. Is carbon moved on a regular schedule? ( ) Yes ( ) No
7. Is carbon dewatering checked before carbon is fed to furnace?
( ) Yes ( ) No
8. Are process control tests (AD's) run during regeneration?
( ) Yes ( ) No
9. Are hearth temperatures logged and are they adequately controlled?
( ) Yes ( ) No
10. Is the regenerated carbon washed to remove fines prior to use?
( ) Yes ( ) No
11. Is the maintenance program adequate? ( ) Yes ( ) No
12. Have the burners been calibrated within a year? ( ) Yes ( ) No
13. Are the alarms and shutdowns adequate? ( ) Yes ( ) No
Are they checked regularly? ( ) Yes ( ) No
14. Are operating records adequate? ( ) Yes ( ) No
15. Is the laboratory and operational office equipped for the necessary analyses? ( ) Yes ( ) No
16. What spare parts are stocked? ____

____

____

17. What are the most common problems the operator has had with the process?

____

____

____

____

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References

1. Culp, G.L. and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, EPA 430/9-78-001.

2. Culp, Russell L., and Culp, Gordon L., Advanced Wastewater Treatment, Van Nostrand Reinhold Co., 1971.

3. CH2M-Hill, Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA Contract 68-01-0328 (June, 1973).

4. Wirts, J.J., et al, Safety in Wastewater Works, Manual of Practice No. 1, Water Pollution Control Federation (1959).

5. Culp/Wesner/Culp, Operation and Maintenance Manual, Water Factory 21, Orange County water District", (June, 1974).

6. CH2M-Hill, Operation and Maintenance Manual for Wastewater Reclamation Facility, South Tahoe PUD, (1976).

7. Culp, R.L., et al, Advanced Wastewater Treatment as Practiced at South Tahoe, U.S. Environmental Protection Agency, Project 17010 ELQ (WPRD 52-01-67), August, 1971.

41. LAND APPLICATION OF SLUDGES

Sludge can be applied to land areas for disposal purposes, crop growing, or to reclaim spoiled land. Application for disposal purposes is identical in concept to a landfill except only the top 1-2 feet of soil are used. Sludge application can be used for providing nutrients and organic matter to crop lands. These systems require careful controls to insure that crop nutrient requirements are met and that no harmful elements such as cadmium are applied in excessive amounts. Reclamation of spoiled land, such as strip mined areas, is a special case similar in scope to application to farm lands. Due to the specialized nature, reclamation will not be discussed. The review procedures would be very similar to those procedures used for crop use but loading rates and use of other materials would be different.

Sludge can be applied as a liquid, dewatered cake, dried matter, or ash. For use with this section, the definitions of these forms are as follows:

Form	Solids Concentration
Liquid	0-10%
Dewatered cake	10-40%
Dried Matter	90-98%
Ash	100%

Application methods vary with site characteristics, use of site and form of the sludge.

Typical Design Considerations, Evaluation, and Control

The loading rate or application rate is a function of the sludge and soil characteristics and crop nutrient requirements. Sludge and soil characteristics and crop requirements vary widely.

The sludge application rate is primarily based on the sludge nitrogen content and the nitrogen requirements of the crop. Nitrogen in sludge is available for immediate plant use in the ammonium (NH_4^+) or nitrate (NO_3^-) forms. The availability of organic nitrogen to the crop depends on the mineralization rate which can be determined after several years of operation.

The heavy metal application rate must also be checked so that recommended maximum are not exceeded.

The procedure for determining the application rate is described in Reference 3. To simplify this Table 41-1 is presented. This table shows application rates for various crops based on the nitrogen requirements, and assuming 70 lb organic nitrogen/ton of sludge, with a mineralization rate of 15-10-5, and an ammonium nitrogen content of 30 lb/ton of sludge.

The monitoring program consists of the analyses shown in Figure 41-1. Sampling and monitoring must be performed by qualified personnel or outside laboratories.

TABLE 41-1. RATE DETERMINATION (tons/acre)

		Application yr				
Crop	Yield, per acre	1	2	3	4	5
		Tons/acre of sludge				
Alfalfa	8 tons	9.1	7.8	7.4	7.0	6.6
Orchard grass	6 tons	7.4	6.3	6.0	5.6	5.4
Corn (grain)	6 tons	4.2	3.6	3.4	3.2	3.0
(stover)	180 bu	1.7	1.5	1.4	1.3	1.2
Sorghum (grain)	8,000 lb	3.0	2.5	2.4	2.2	2.1
(stover)	8,000 lb	3.2	2.7	2.6	2.4	2.3
Corn silage	32 tons	5.9	5.0	4.8	4.5	4.3
Oats (grain)	100 bu	2.0	1.7	1.6	1.5	1.4
(straw)		0.86	0.74	0.70	0.66	0.62
Soybeans (grain)	60 bu	6.0	5.1	4.8	4.6	4.3
(straw)	7,000 lb	2.1	1.8	1.7	1.6	1.5
Wheat (grain)	80 bu	3.6	3.0	2.9	2.7	2.6
(straw)	6,000 lb	1.0	0.89	0.84	0.79	0.75
Barley (grain)	100 bu	2.7	2.3	2.2	2.1	2.0
(straw)		1.0	0.84	0.80	0.75	0.71

Sensory observations can detect many problems before environmental monitoring tests. When injecting sludge, the application rate should be such that sludge does not surface. If sludge surfaces, the injector speed should be increased or the sludge flow decreased so that the quantity injected per unit area decreases. If the injector travel speed is excessive, soil may be thrown away from the shank creating an open trench.

If the sludge is spread on the surface, the rate should be low enough to prevent the excessive ponding or runoff. Excessive ponding is when the liquid is still above the surface several hours after application. Either excessive ponding or runoff indicates excessive application rates for the soil. This will vary widely from soil to soil.

Maintenance Considerations

Maintenance requirements are mainly cleaning and equipment service. The cleaning operation include daily flushing of the injectors (if used) and periodic flushing of the tanks. Truck, tractor, and equipment preventative maintenance schedules will be specified in manufacturer's data.

Records

In addition to the normal record kept for monitoring and process control, the field operator(s) must keep a daily log or site map record to show where, when, and how much sludge has been applied.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

LAND APPLICATION OF SLUDGES

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TDS	ALL	W	Sl	G	P
	COD	ALL	W	Sl	G	P
	TKN	ALL	W	Sl	G	P
	NH_3-N	ALL	W	Sl	G	P
	NO_3-N	ALL	W	Sl	G	P
	P	ALL	W	Sl	G	H
	FECAL COLIFORM	ALL	M	Sl	G	P
	FECAL STREP	ALL	M	Sl	G	P
	SALMONELLA	ALL	M	Sl	G	P
	CYSTS	ALL	M	Sl	G	P
	pH	ALL	D	Sl	G	P
	Cl	ALL	M	Sl	G	P
	ALKALINITY	ALL	W	Sl	G	P
OPTIONAL	METALS (Cd,Zn, Cu,Pb, Ni)	ALL	M	Sl	G	P
	Na	ALL	M	Sl	G	P
	K	ALL	W	Sl	G	P
	B	ALL	M	Sl	G	P
	TKN	ALL	A	So	G	P
	NH_4-N	ALL	A	So	G	P
	P	ALL	A	So	G	P
	K	ALL	A	So	G	P
	ALKALINITY	ALL	A	So	G	P

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

SL =SLUDGE BEING APPLIED
SO =SOIL
M =MONITORING WELLS OR NEARBY BY STREAMS

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 41-1

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

LAND APPLICATION OF SLUDGES

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	CONTROL EXCH. CAPACITY	ALL	A	So	G	P
	SALMONELLA	ALL	A	So	G	H
	CYSTS	ALL	A	So	G	H
	CHLORIDE	ALL	A	So	G	P
	B	ALL	A	So	G	P
	pH	ALL	M	So	G	P
	COLIFORM	ALL	M	M	24C	P
	FECAL COLIFORM	ALL	M	M	24C	P
	NO_3-N	ALL	M	M	24C	P
	TDS	ALL	M	M	G	P
OPTIONAL						

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

SL = SLUDGE BEING APPLIED
SO = SOIL
M = MONITORING WELLS OR NEARBY BY STREAMS

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

Figure 41-1 (cont'd)

Laboratory Equipment

The laboratory should include the following minimum equipment in order to monitor land application:

1. Analytical balance
2. Blender
3. Fume hood
4. Incubator
5. Kjeldahl digesting and distilling apparatus
6. Oven
7. pH meter
8. Pump (vacuum-pressure)
9. Spectrophotometer
10. Sterilizer
11. Titrator-amperometric

Sampling Procedures

Sampling should be done on representative sludge and soil. Sludge that has been in storage for overnight should not be sampled for nitrogen forms or pH. "Fresh" sludge should be used for samples to set loading rates.

Similarily, soil samples should be taken from areas of the field that predominate. In other words if a field consists mainly of a clay-loam with an isolated area of sand, then the samples should be taken from the loam areas and not in the sandy area. This does not mean the sandy area should be ignored but rather that the overall loading rates should be based on results from samples taken in the loam soil.

Sidestreams

With a properly operated and maintained land application system there should be no sidestreams. The land application system should be designed such that accidental spills will be contained and sludge will not enter surface water.

Process Checklist - Land Application

A. General

1. Is sludge application for disposal only, crop utilization, or reclamation of spoiled area? (circle one)
2. Does site visit reveal any areas of runoff or ponding? ( ) Yes ( ) No
3. Is emergency storage provided? ( ) Yes ( ) No
4. Are field records in order? ( ) Yes ( ) No
5. Is a preventive maintenance plan in use? ( ) Yes ( ) No
6. Is there an emergency plan for power outages or major equipment failures? ( ) Yes ( ) No
7. Does the sampling program meet recommendations? ( ) Yes ( ) No
8. Is an O&M manual available? ( ) Yes ( ) No
9. Is O&M manual used? ( ) Yes ( ) No
10. Is laboratory properly equipped? ( ) Yes ( ) No
11. What spare parts are stocked?
12. What are the most common problems the operator has had with the process?

B. Farming (if applicable)

1. Is farming done by agency staff and equipment? ( ) Yes ( ) No
2. Is farming done by contract? ( ) Yes ( ) No
3. What crops are grown?
4. Are crops rotated? ( ) Yes ( ) No
5. Are nutrient requirements calculated and are supplementary fertilizers used? ( ) Yes ( ) No

References

1. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 14th Edition, 1975. Washington, D.C.

2. Knezek, B.D., and Miller, R.H. (ed.) Application of Sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide, North Central Regional Research Publication 235, Columbus, Ohio.

3. Ettlich, W.F. et al, Operations Manual Sludge Handling and Conditioning, U.S. EPA, Office of Water Program Operations, Washington, D.C., 430/9-78-002, February 1978.

42. LANDFILL

Process Description

Burying sludge to minimize nuisance conditions or public health problems is called landfill. Sludge is buried in layers which are covered with fill material excavated at the site. Landfills must be located where nearby wells or groundwater supplies will not be contaminated by leachate from the fill operation. Sludge landfills are generally separate from refuse landfills.

Typical Design Considerations

Loading rates for landfill operations and soil layer depths for a typical site are given in Table 42-1.

TABLE 42-1. DESIGN CRITERIA

Trench width	
Bottom	12 ft
Top	28 ft
Trench length	50 ft
Sludge layer	2 ft
Intermediate fill layer	1 ft
Top fill cover	3-5 ft
Distance between trenches	15 ft
Distance from property line	150 ft
Distance from drainage ditch	30 ft

The depths are required for safety (to prevent contamination of adjacent areas and to prevent cell or trench cave-ins) and for ease of operations with conventional excavation equipment. Variations deppend on special site characteristics.

Typical Performance Evaluation

Performance of a landfill is measured as a function of disposal without harming the surrounding environment or producing nuisances.

A landfill system can be operated such that no odors or vector habitats are produced. There should be no runoff or change in natural drainage. Leachate is controlled by not trenching to an elevation less than 15 to 20 feet above the impervious layer. Leachate quantity can be minimized by pumping excess from the trench to a tanker truck. Unlike most other processes, this one either succeeds or fails with little margin for partial failure.

Successful operation of a landfill system is measured by monitoring wells and nearby surface streams and by sensory observations.

There should be several monitoring wells located just inside the site boundaries. Well depths are variable. The wells should consist of a 6-inch pipes fitted with a threaded cap on top and a well screen at the bottom (or equivalent). These pipes are normally placed in 16-inch borings, which are packed with 3/5 to 1-1/2-inch gravel. Sampling can be accomplished through the use of a portable pump and a 20-foot, 4-inch pipe with a foot valve at the bottom. These wells and domestic wells within 1/4 mile of the landfill should be sampled prior to startup of the landfill.

Table 42-2 shows a list of constituents to be included in the well monitoring.

TABLE 42-2. WELL ANALYSIS

Boron	TDS
Cadmium	pH
Copper	Chloride
Iron	Phosphorus
Lead	NO_2-NO_3
Mercury	Total coliform
Zinc	Fecal coliform
	Fecal streptococcus

The drainage ditch should be monitored during flow periods. The ditch monitoring points should be at the two points where the ditch crosses the site. The difference between the upstream and downstream locations will show if there is an increase due to the landfill operation.

Table 42-3 shows the tests to be done on the drainage ditch flows.

TABLE 42-3. DRAINAGE DITCH ANALYSIS

Fecal coliform	NO_3
Coliform	NH_3
Suspended solids	Phosphorus
BOD	pH

The monitoring wells are sampled monthly. The drainage ditch is sampled when rainfall occurs but no more than once per week. The domestic wells are sampled quarterly.

Process Control

Landfill controls consist of surface runoff management to prevent runoff from passing through the fill site. The process is controlled by varying the layers of sludge and/or fill material. If the moisture content of the sludge increases then smaller layers of sludge would be placed in the trench.

Maintenance Considerations

Vehicle maintenance should include preventative maintenance in accordance with manufacturer's guidelines and daily inspection.

Daily inspection should include the following:

Fuel level
Oil level
Battery
Tires (or tracks)
Hydraulic systems (where applicable)
Grease crane and crawler
Turn signals and brake lights on trucks

Completed landfill areas should be seeded and observed to insure that grass distribution is adequate and that there are no exposed soil areas.

Records

Records for this process consist of laboratory analyses records of monitoring wells and nearby drainage areas, notation of visual or sensory observations, weather records, and maps showing areas filled and dates of filling.

Sampling locations and frequencies are shown on Figure 42-1.

Laboratory Equipment

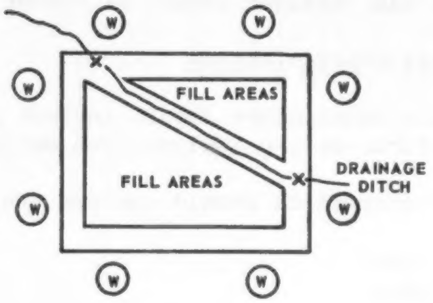
The following laboratory equipment items are required for monitoring a landfill operation:

1. Analytical balance
2. Blender
3. Fume hood
4. Incubator
5. Kjeldahl digesting and distilling apparatus
6. Oven
7. pH meter
8. Pump (vacuum-pressure)

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BORON	ALL	S	W		
	CADMIUM	ALL	S	W		
	COPPER	ALL	S	W		
	IRON	ALL	S	W		
	LEAD	ALL	S	W		
	MERCURY	ALL	S	W		
	ZINC	ALL	S	W		
	TDS	ALL	S	W		
	pH	ALL	M	W,D		
	CHLORIDE	ALL	M	W		
	PHOSPHORUS	ALL	M,A	W,D		
	NO_2-NO_3	ALL	M,A	W,D		
	TOTAL COLIFORM	ALL	M,A	W,D		
	FECAL COLIFORM	ALL	M,A	W,D		
	FECAL STREPTOCOCCUS	ALL	M,A, S	W,D		
OPTIONAL	SUSPENDED SOLIDS	ALL	A	D		
	BOD	ALL	A	D		
	NH_3	ALL	A	D		

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

LANDFILL



A. TEST FREQUENCY

S = SEMI-ANNUAL	M = MONTH
A = AS REQUIRED AFTER RAINFALL	R = RECORD CONTINUOUSLY
	Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

W = WELL (Ⓦ)
D = DITCH

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

1. THESE TESTS SHOULD ALSO BE RUN ON RECEIVING WATER, ABOVE AND BELOW OUTFALL, ON A PERIODIC BASIS, DEPENDING ON LOCAL CONDITIONS.
2. FOR PLANTS DESIGNED TO CONTROL THIS PARAMETER.

Figure 42-1

9. Spectrophotometer
10. Sterilizer
11. Titrator-amperometric

Sidestreams

The sidestream from a landfill operation is the leachate. There is very little that can be done to control leachate from a landfill operation. Generally, leachate is controlled by selecting a site with no underlying groundwater or with an impermeable soil layer between the fill bottom and groundwater. Under certain conditions liners or clay soil layers are allowed to hold moisture and minimize leachate movement.

Process Checklist - Landfill

1. Is emergency storage available for periods of rainy weather (2 weeks or more)? ( ) Yes ( ) No
2. Are trenches dug in advance of fill operation? ( ) Yes ( ) No
3. Do operators maintain safe distance from edge of trench? ( ) Yes ( ) No
4. Are trenches covered each night at end of shift? ( ) Yes ( ) No
5. Are odors present? ( ) Yes ( ) No
6. Are flies present? ( ) Yes ( ) No
7. Are rodents a problem? ( ) Yes ( ) No
8. Are filled areas revegetated? ( ) Yes ( ) No
9. Is there a scheduled maintenance plan? ( ) Yes ( ) No
10. Are maintenance records current? ( ) Yes ( ) No

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1. Lukasik, G.D., and Cormack, J.W., "Development and Operation of a Sanitary Landfill for Sludge Disposal", paper presented at EPA 208 Seminar, Reston, Virginia, March 16, 1977.

2. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 14th Edition, 1975, Washington, D.C.

3. Culp, G.L., and Folks Heim, N., Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, US EPA Report 430/9-78-001 (Jan. 1978).

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